National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

Canada

UNIVERSITY OF ALBERTA

EFFECT OF FLOOR-APPLIED MINERAL OIL AND PIG ACTIVITY ON DUST IN A FARROWING UNIT

©

by

Sarah Lynn Perkins

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

DEPARTMENT OF ANIMAL SCIENCE

Edmonton, Alberta
Spring 1994.

National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-612-11326-4

Canada

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Sarah Lynn Perkins

TITLE OF THESIS: Effect of Floor-Applied Mineral Oil and Pig Activity on Dust in a Farrowing Unit

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 1994

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as hereinbefore provided neither the thesis nor any substantial portion thereof may be printed or otherwise reproduced in any material form whatever without the author's written permission.

Sarah Perkins

Sarah Perkins,
R.R. # 2,
Dobbinton, ON
N0H 1L0

Apr 22/94

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled EFFECT OF FLOOR-APPLIED MINERAL OIL AND PIG ACTIVITY ON DUST IN A FARROWING ENVIRONMENT submitted by SARAH LYNN PERKINS in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

John Feddes

Dr. J.J.R. Feddes

Leonard

Dr. J.L. Leonard

Robert T. Hardin

Dr. R.T. Hardin

April 21, 1994

EFFECT OF FLOOR-APPLIED MINERAL OIL AND PIG ACTIVITY ON DUST IN A FARROWING UNIT (abstract)

Evidence exists that suggests a relationship between air quality in swine barns and respiratory health. Methods of dust control are necessary to protect worker and animal health. Several researchers have found that various types of oil act as a dust suppressant when applied to feed, poultry litter or floors in swine units.

Three farrowing rooms each housing 5 sows and litters were used to study the effects of floor-applied mineral oil on dust concentrations (>0.5 μm diameter). Rooms were ventilated at a similar rate (266 L/s). An experiment was designed with 3 treatments and 2 replicates/treatment. No oil was sprayed in the control treatment. Oil was applied either once a week for three weeks or once at the beginning of week one in the remaining 2 treatments. Oil was applied to crate floors (61 mL oil/m^2) using a low-pressure hand sprayer. Treatments were repeated using an application rate of 24 mL/m^2. Dust concentrations (particles/mL), maximum, minimum, wet and dry-bulb temperature, ventilation rate and number of piglets and total piglet mass per room were recorded weekly for a three week period.

Mean temperatures were 28, 24, 21 and 27°C for maximum, minimum, wet and dry-bulb temperatures, respectively. There was no difference in ventilation rate between treatments or rooms. Dust concentrations were reduced by applying oil (3.2, 0.7 and 2.6 particles/mL, control, weekly and single applications, respectively). There was an increase in dust concentrations with time, the greatest increase occurring between weeks 2 and 3. Applying oil weekly resulted in an average dust reduction of 73% on the day after oil was applied. More work is required to determine the duration of dust-suppression by oil.

Dust levels obtained in the experiment were lower than expected. Preliminary work suggested that sampling through 17.7 m of tubing reduced particle levels by 30-40%. A 5 x 5 Latin square using 5 lengths of tube (0, 4.6, 9.2, 13.8 and 18.4 m) was designed to quantify the effects. The square was repeated 4 times. Mean percent recovery at 18.4 m was 38%. Particle levels obtained in the experiment involving mineral oil were adjusted for the effects of sampling technique.

A third experiment was conducted to determine the relationship between animal activity and dust concentration. One sow and litter were housed in a room with one raised farrowing crate. Particle levels and animal activity were video recorded for a continuous 6-h period. Animal activity was classified into several categories and the number of piglets in each category recorded. The experiment was repeated with 3 different litters.

Litter effects accounted for 25% of dust variation. When considered on their own, number of piglets quiet, standing or engaging in intense activity explained the largest amounts of within-litter variation (R^2 = 0.46, 0.29 and 0.14, respectively). Sow activity explained little variation in dust. Proportion of piglets active accounted for 29% of within-litter variation in dust.

Dust concentrations are highest during animal activity. Dust control methods are needed during high activity periods to protect respiratory health. Applying oil to floors weekly may be an effective means of dust reduction in swine barns.

ACKNOWLEDGEMENTS

The following people from the Centre for Food and Animal Research, Ottawa are to be acknowledged for their assistance. Dr. David Fraser, for his excellent supervision during my stay in Ottawa. His assistance with the design and analysis of the tubing and activity experiments is also appreciated. The Electrical and Engineering shops are thanked for their quick and expert assistance during equipment failures. Thank you also to the Barn Staff at the swine unit for their wonderful cooperation throughout the course of my research. I would also like to thank Leah Braithwaite for her assistance with various aspects of this project.

A word of thanks also to Dr. John Feddes, whose supervision throughout the course of my degree was deeply appreciated. I have enjoyed the opportunity of working with you.

Financial assistance from the Alberta Pork Producers Development Corporation was greatly appreciated.

A special acknowledgement to my parents and friends, both in Alberta and Ontario, for their support and encouragement. An additional word of gratitude to the Cheerio gang for helping to keep this "O" cheery.

TABLE OF CONTENTS

EFFECT OF FLOOR-APPLIED MINERAL OIL AND PIG ACTIVITY ON DUST IN A FARROWING UNIT i

ACKNOWLEDGEMENTS ii

TABLE OF CONTENTS iii

LIST OF TABLES v

LIST OF FIGURES vi

LIST OF ABBREVIATIONS vii

CHAPTER 1 INTRODUCTION AND LITERATURE REVIEW 1
INTRODUCTION 1
LITERATURE REVIEW 1
Definitions and Characterization of Dust 1
Pig Health 2
Worker Health 5
Recommended Exposure Levels 6
Strategies for Dust Control 8
REFERENCES 9

CHAPTER 2 EFFECTS OF FLOOR-APPLIED MINERAL OIL ON RESPIRABLE DUST IN A SWINE FARROWING ENVIRONMENT 12
INTRODUCTION 12
Oil as a Feed and Grain Additive 12
Oil Application to Litter and Floors 13
OBJECTIVES 14
MATERIALS AND METHODS 14
Facilities 14
Experimental Design 15
Oil Application 17
Dust Monitoring 18
Temperature Monitoring 20
Ventilation Rate 20
Piglet Weights 21
Statistical Analysis 22
RESULTS 22
Dust 22
Temperature 26
Ventilation Rate 27
Piglet Weights 28
DISCUSSION 29
REFERENCES 31

CHAPTER 3 EFFECTS OF TUBING LENGTH ON PARTICLE COUNTS 33
INTRODUCTION 33
OBJECTIVES 33
MATERIALS AND METHODS 33

Experimental Design 33
Facilities and Equipment 33
Experimental Protocol 34
Statistical Analysis 35
RESULTS 35
DISCUSSION 37
CONCLUSIONS 37
REFERENCES 39

CHAPTER 4 PRESENTATION OF ADJUSTED PARTICLE LEVELS AND DISCUSSION 40
INTRODUCTION 40
RESULTS 40
DISCUSSION 42
CONCLUSIONS 45
REFERENCES 47

CHAPTER 5 EFFECTS OF SOW AND PIGLET ACTIVITY ON AIRBORNE DUST CONCENTRATIONS IN A FARROWING UNIT 48
INTRODUCTION 48
OBJECTIVES 49
MATERIAL AND METHODS 49
Experimental Facility 49
Sampling Equipment 50
Experimental Protocol 51
Activity Scoring 51
Statistical Analysis 53
RESULTS 53
DISCUSSION 57
CONCLUSIONS 59
REFERENCES 61

CHAPTER 6 GENERAL DISCUSSION AND CONCLUSIONS 62
REFERENCES 65

APPENDIX FOR CHAPTER 2 67

LIST OF TABLES

Table I-1 Survey of respiratory disease of Ontario farmers (Choinière and Munroe, 1993b) 5
Table I-2 Respiratory disease prevalence in dairy and swine workers (Iversen et al., cited by Pedersen (1989)) 6
Table I-3 Clinical symptoms in swine confinement workers 6
Table I-4 OSHA recommended exposure limits for grain dust (Choinière and Munroe, 1993a) 7
Table I-5 Recommended guidelines for dust exposure limits (Donham, 1991) 7
Table II-1 Order of oil applications 16
Table II-2 Weekly schedule of events for control, weekly and single oil applications 17
Table II-3 Mean dust concentrations (particles/mL) by week, control, weekly and single mineral oil applications 26
Table II-4 Summary of mean temperatures (^{o}C) by treatment 27
Table II-5 Summary of mean weekly and overall ventilation rates (in L/s) for control, weekly and single oil applications 27
Table II-6 Mean total piglet mass (kg), average piglet mass (kg) and average piglet age (d), summarized by week and treatment 29
Table III-1 Order of treatments for 5 x 5 Latin square 34
Table III-2 Mean percent dust recovery for various lengths of tubing 36
Table IV-1 Weekly means and ranges for particle concentrations (particles/mL) for control, weekly and single mineral oil applications in a farrowing unit 40
Table IV-2 Adjusted mean particle concentration by treatment for control, weekly and single oil applications in a farrowing unit 41
Table IV-3 Mean particle production rates (particles/(s.pig)) for control, weekly and single oil applications 41
Table IV-4 Weekly particle production rates (particles/(s.pig)) for control, weekly and single oil applications 42
Table V-1 Categories and criteria used to score piglet and sow activity 53
Table V-2 Date and time of recording and age and number of piglets used in activity scoring 54
Table V-3 Squared Pearson partial correlation coefficients with particle concentration of within-litter variation 56
Table V-4 R-squares and partial R-squares for stepwise regression of within-litter variation 57
Table V-5 R-squares and partial R-squares for proportion of piglets active 57

LIST OF FIGURES

Figure II-1 Schematic of farrowing crates illustrating crate size differences for rooms with 5 or 6 crates/room 15
Figure II-2 Dates of dust monitoring, replicates 1 and 2 16
Figure II-3 Diagram of farrowing room and sampling locations 19
Figure II-4 Diagram of duct used to monitor ventilation rate 21
Figure II-5 Graphs of dust concentration vs time, replicates 1 and 2 week 1 23
Figure II-6 Graphs of dust concentration vs time, replicates 1 and 2 week 2 24
Figure II-7 Graphs of dust concentration vs time, replicates 1 and 2 week 3 25
Figure II-8 Piglet growth curve 28
Figure III-1 Regression of percent dust recovery on tube length 36
Figure V-1 Schematic of room, illustrating location of video cameras and dust sampling equipment 50
Figure V-2 Example of plot of dust concentration vs time used to select the 3-h period of activity scoring 52
Figure V-3 Particle concentration and proportion of pigs active vs time, litter 3 54
Figure V-4 Particle concentration and proportion of pigs active vs time, litter 2 55
Figure V-5 Particle concentration and proportion of pigs active vs time, litter 3 55

LIST OF ABBREVIATIONS

µm	=	microns
AR	=	atrophic rhinitis
cm	=	centimetres
CF	=	cubic foot
CO_2	=	carbon dioxide
d	=	days
d.f.	=	degrees of freedom
h	=	hours
kg	=	kilogram
L/s	=	litres per second
mg/m^3	=	milligrams per cubic metre
NH_3	=	ammonia
ODTS	=	organic dust toxic syndrome
ON	=	Ontario
PA	=	proportion of piglets active
particles/mL	=	dust particles per millilitre air
particles/(s.pig)	=	particles per second per piglet
PIA	=	piglets intense activity
PLA	=	piglets lying active
PQ	=	piglets quiet
PS	=	piglets standing
PU	=	piglets on udder
RD	=	respirable dust
s	=	second
SAS	=	Statistical Analysis System
SEM	=	standard error of the mean
T_{db}	=	dry-bulb temperature
T_{max}	=	maximum temperature
T_{min}	=	minimum temperature
TRT	=	treatment
T_{wb}	=	wet-bulb temperature
wk	=	week
wks	=	weeks
r^2	=	partial R-square

CHAPTER 1 INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Over the past several decades, there has been a shift from extensive livestock production to more intensive confinement systems. McQuitty (1967) lists many factors that have led to intensification and a more efficient use of labour. These include an increasing human population, demand by urban areas for land for roads, recreational facilities etc., competition between industry and farming for labour and changes in the world food system that demand more efficient production. The greatest changes in livestock production have occurred in animal housing. Often animal housing is used as a labour saving device, rather than as a way to provide animal shelter (Curtis, 1972). With the increase in intensive livestock production units, new problems have been introduced. Handling and disposal of animal wastes, odour emissions and disease control, especially respiratory diseases, have become particular challenges to producers (McQuitty, 1967).

Recently researchers have investigated the relationship between air quality and respiratory disease. Curtis (1972) states that the air environment includes dust, liquid droplets, microorganisms, gases, odours and ions. Dust from animal activity and feed distribution (Bundy and Veenhuizen, 1987), and gases from animal respiration and manure decomposition (Hellickson et al., 1989) can also accumulate in the animal's environment. Aerial contaminants can shorten equipment life and impair its proper function (Phillips, 1986). Additionally, these aerial contaminants may pose health risks to both animals and workers that spend prolonged periods in these environments (DeBoer and Morrison, 1988). Dust concentration is of particular concern in swine and poultry units (Donham et al., 1990; Donham and Gustafsson, 1982). A question that now needs to be considered is whether, for each class of livestock, there is a level of aerial contaminants at which continuous exposure affects animal performance (Curtis, 1972).

LITERATURE REVIEW

Definitions and Characterization of Dust

Carpenter (1986) in a review of dust in livestock buildings defines aerosol as any solid or liquid particle that remains airborne indefinitely. He further states that dust implies solid particles of wide size range. Viable particles are defined as any particle, either liquid or solid that contains a living microorganism. Airborne spores

may also be classified as viable particles. Dust in livestock barns is almost entirely organic (Carpenter, 1986) and is widely diverse in size and composition. Particles in swine barns can be composed of feed, feces, dander, molds, insect parts, mineral ash or pollens and grains (Donham et al., 1986). As well, viruses or bacteria may become airborne and adhere to other particles (Choinière and Munroe, 1993a). Donham et al. (1986) reported that hog dust crude protein content was 22.6%. Particles in swine barns are biologically active and will react with respiratory tissues if inhaled (Choinière and Munroe, 1993a).

Inhaled particles are deposited in the respiratory system by three methods: diffusion, sedimentation and impaction. However, the site of deposition is determined by the particle size (Mercer, 1978). Particles <10 µm in diameter are deposited in the nose, particles with diameters between 5-10 µm are generally deposited in the upper respiratory tract and particles with diameters < 5 µm are deposited in the lower respiratory tract (Carpenter, 1986). Several terms are used to classify dust. Inspirable dust is the fraction which enters the mouth and nose during breathing (Boon, 1992). Respirable particles are those small enough to penetrate gas exchange regions of the lungs (DeBoer and Morrison, 1988; Boon, 1992) and in this thesis are defined as between 0.5 - 5 µm in diameter. Curtis (1987) reported that 25 - 33% of particles in hog units are respirable, while Donham and Gustafsson (1982) reported that 15% of swine dust was respirable. Choinière and Munroe (1993a) state that between 80-90% of total swine dust is respirable. Another study (Nicks et al., 1993) reported that 99% of dust was in the respirable range. Both workers and animals can be exposed to large amounts of potentially harmful dusts. The majority of dust mass is composed of particles ≥ 3 µm in diameter. However, the greatest number of particles are <1 µm diameter (Carpenter, 1986).

Pig Health

Carpenter (1986) lists four means by which dust can affect the health and growth rate of livestock. Dust may: **1)** act as a respiratory irritant **2)** lower resistance to respiratory diseases. **3)** carry pathogens into lung tissues, or **4)** carry large concentrations of non-pathogenic organisms into the lungs. High levels of non-pathogens may also influence the prevalence of respiratory disease.

Castranova et al. (1992) conducted a study to determine responsiveness of guinea pigs to dusts known to cause ODTS (organic dust toxic syndrome) in dairy farmers. Guinea pigs were exposed to dust for a 6-h

period and examined immediately or 18 h post exposure. General respiratory responses to respirable dust included an increase in the number of total alveolar cells, polymorphonuclear leukocytes, lymphocytes and red blood cells. In addition, an increase in secretory action of macrophages and in breathing rate and airway closure were reported. In a similar study, Robinson et al. (1992) studied airway response in small, medium and large sized guinea pigs. Responses similar to those listed above were observed. Although there was no difference in responsiveness between small and medium sized guinea pigs, both groups were significantly more sensitive than large guinea pigs. The researchers concluded that the guinea pig was a useful model for predicting biological activity of various dusts (Castranova et al., 1992).

Nasal passages filter, humidify and warm incoming air (Switzer et al., 1981). If nasal passages are damaged, these functions can be impaired and lower respiratory tract damage may be more severe. Doig and Willoughby (1971) exposed week old piglets to various levels of dust and NH_3. When pigs were exposed to dust or NH_3 alone, some conjunctival irritation was observed during the first week of exposure. After this period, pigs acclimatized. However, in pigs exposed to both dust and NH_3, conjunctival irritation lasted 2 weeks. Pigs exposed to dust and NH_3 for 5 weeks exhibited extensive cilia loss. In addition, pigs exposed to NH_3 alone or with dust had decreased numbers of goblet cells and increased turbinate epithelium thickness. The authors reported histopathological changes in the upper respiratory tract only. Pigs were exposed to contaminants for a maximum of 6 weeks. If pigs were exposed to these contaminants for a longer period, evidence of lower tract damage may also have been observed.

Pneumonia and atrophic rhinitis (AR) are both common respiratory diseases in swine. Usually these diseases are both subclinical, having detrimental effects on weight gain and feed efficiency in pigs (Cowart et al., 1992). In one study, pigs were exposed to either respirable dust (RD), RD and NH_3 or to a control environment. Pigs were then intranasally challenged with Pasturella multocida, a causative agent of AR. At the conclusion of the experiment, pigs were scored for AR severity. Pigs in the control environment had normal turbinates while those exposed to pollutants had moderate turbinate scores. Pigs that were exposed to both RD and NH_3 showed the greatest increase in AR score. Continuous exposure to aerial pollutants may contribute to severity of turbinate atrophy (Hamilton et al., 1993).

Continuous production (vs all-in all-out systems), small airspace/animal, incorrect room temperatures and high carbon dioxide (CO_2) concentrations may all be associated with adverse health effects (Awad-Masalmeh and Köfer, 1993). Research by Cowart et al. (1992) compared both farrowing and grower-finisher units with mechanical and natural ventilation to relate AR and pneumonia to season and found that AR incidence was significantly higher in summer. The opposite was found for pneumonia scores, which were significantly higher in the winter. In both farrowing and grower-finisher barns, AR incidence was higher in the intensely confined, mechanically ventilated barns. This trend was consistent in both winter and summer conditions. Pigs that developed AR during the summer were farrowed in the winter, when dust concentrations are highest. The researchers hypothesized that exposure to poorer air quality during the winter may have rendered the pigs more susceptible to infection by agents that cause AR.

Donham (1991) studied various aerial contaminants in swine barns and correlated them to respiratory disease. He stated that respirable dust and NH_3 concentrations at animal level and CO_2 concentration at worker level were most consistently related to respiratory disease in pigs. However, Doig and Willoughby (1971) reported no changes in average daily gain when pigs were exposed to dust and NH_3 alone or in combination. Curtis et al. (1975) reported decreased rate of gain in pigs exposed to 300 mg/m^3 of dust with 50 ppm NH_3. However, when exposed to dust at levels of 10 mg/m^3 with 50 ppm NH_3, no effect on performance was observed. This agrees with Backström and Curtis (1981) who reported that dust often exceeds levels of 10 mg/m^3, but this has little direct influence on pig health or performance. Jansen and Feddes (1993) exposed pigs to either feed or fecal dust during the growing phase. Pigs were exposed to high dust concentrations (approximately 80 particles/mL) 14 h/day for approximately 90 days. Lungs were removed at slaughter and scored according to the percent of lung affected by lesions. They reported that dust exposure had little effect on animal performance, however, they did find that younger, lighter animals may be more susceptible to lung lesions when housed in conditions of poor air quality. They concluded that dust may have a greater influence on the incidence, rather than the severity of lung lesions. Curtis et al. (1975) reported that effects of dust and NH_3 were additive. This agrees with Jansen and Feddes (1993). Although contaminants may not be high enough in swine units to influence pig performance, respiratory health may be compromised.

Worker Health

Respirable dust may also threaten the health of labourers that work in these environments for prolonged periods of time. Common respiratory problems that can develop as a result of chronic exposure include chronic bronchitis, occupational asthma and farmer's lung (Choinière and Munroe, 1993b). In addition, symptoms are more severe and more frequent among hog workers than among dairy, beef, poultry and mixed farmers (Donham and Gustafsson, 1982; Donham, 1987; Holness et al., 1987). Table I-1 compares the incidence of respiratory diseases in Ontario dairy, swine and poultry producers.

Table I-1 Survey of respiratory disease of Ontario farmers (Choinière and Munroe, 1993b)

DISEASE	*DAIRY (%)*	*SWINE (%)*	*POULTRY (%)*
Acute Bronchitis	N/A	70-90	15-25
Chronic Bronchitis	10-20	15-30	8-15
Occupational Asthma	4-7	20-30	5-10
ODTS	N/A	20-30	N/A
Farmer's Lung	2-10	N/A	N/A

N/A = Not available

The major respiratory complaints of swine workers included cough, chest tightness, excess sputum, wheezing and shortness of breath. Twelve percent of labourers reported symptoms 2-3 h post exposure. These symptoms usually improved after 24-48 h away from production units (Donham and Gustafsson, 1982). In a comparison of swine confinement workers, non-confinement agricultural workers and blue-collar non-agricultural workers, Donham et al. (1990) reported that more confinement workers reported a "usual cough" (15 vs 9.5 vs 8% for confinement, non-confinement and blue-collar, respectively). A similar trend was reported for phlegm production (25, 11, 10% confinement, non and blue-collar, respectively) and developing a cough after a 48-h absence from work (18, 2.5, 4.7%, confinement, non and blue-collar, respectively). Iversen et al., cited by Pedersen (1989) compared respiratory disease prevalency between dairy and swine workers. Their results are summarized in Table I-2 . A summary of clinical respiratory symptoms in swine workers is presented in

Table I-2 Respiratory disease prevalence in dairy and swine workers (Iversen et al., cited by Pedersen (1989))

DISEASE	*DAIRY*	*SWINE*
Asthma	5.5 %	10.9 %
Chronic bronchitis	17.5 %	32.0 %

Table I-3. Iversen and Takai (1990) studied both symptomatic and asymptomatic workers and found the mean age of workers was significantly higher for symptomatic farmers (50 vs 35, symptomatic vs asymptomatic, respectively). This may indicate that serious damage may occur over a prolonged period of time. In a survey of self-reported behaviours of swine workers, Gjerde et al. (1991) found that >80% of labourers were concerned about the long term health effects of farming. However, <20% felt they were as careful about the risks as they could be. Moreover, <10% of those surveyed knew what the recommended exposure levels for common livestock gases and dust were.

Table I-3 Clinical symptoms in swine confinement workers

SYMPTOM	*%*
Asthma-like	10-12
Acute/sub-acute bronchitis	70-90
Organic dust toxic syndrome (ODTS)	10-15
Chronic bronchitis	55
Obstructed airway	38

(Donham, 1987)

Recommended Exposure Levels

The ability of a particle to cause a biological reaction depends on several factors. The ability of the particle to enter the respiratory system, the deposition site, retention time in respiratory structures, rate of absorption and biological activity are all factors that must be considered when determining recommended exposure limits (NRCC, 1982). Several organizations have developed exposure limits for grain or nuisance dusts.

Table I-4 presents recommendations from Ontario's Occupational Health and Safety Act (OSHA) for grain dust.

Table I-4 OSHA recommended exposure limits for grain dust (Choinière and Munroe, 1993a)

DUST TYPE	*TWAEV* [a]	*CEV* [b]
Grain (mg/m^3)	4	20
Total (mg/m^3)	10	50
Respirable (mg/m^3)	5	25

[a] = Time weighted average exposure value
[b] = Ceiling exposure value

The British Standards Institution (cited by Boon, 1992) has set recommended limits of 10 mg/m^3 for total inhalable dust and 5 mg/m^3 for total respirable dust. A maximum exposure limit of 10 mg/m^3 was set for grain dust. A study of Ontario pork producers found that 27% of workers were exposed to levels >10 mg/m^3 (Choinière and Munroe, 1993a). In addition, the standards set for dust exposure often do not account for multiple exposures or synergistic effects of aerial contaminants (Boon, 1992). Research by Donham et al. (1986) states that present recommendations may be too high to prevent respiratory disease in workers and that current standards should be much lower. Table I-5 shows his recommended guidelines for area and personal dust for both humans and pigs. Area samples were taken at stationary sampling locations. Personal samples were collected within the worker breathing zone.

Table I-5 Recommended guidelines for dust exposure limits (Donham, 1991)

	HUMANS	*SWINE*
Total dust area (mg/m^3)	2.4	3.7
personal (mg/m^3)	3.8	-
Respirable dust area (mg/m^3)	0.23	0.23
personal (mg/m^3)	0.28	-

Strategies for Dust Control

In order to provide a healthier environment for both swine and humans, it is important to control dust emissions. There are 3 basic strategies to dust control (Dawson, 1990; Bundy, 1984):

1. Minimize dust formation
2. Prevent formed dust from becoming airborne
3. Removal of dust particles once they become airborne

Initially, this thesis addresses the second strategy and examines the use of floor-applied mineral oil as a means of controlling airborne dust concentrations in a swine farrowing environment. Secondly, this thesis describes an experiment to examine the relationship between pig activity and dust concentrations. On the basis of this experiment, a model was developed to determine those activities which have the greatest influence on dust levels.

REFERENCES

Awad-Masalmeh, M. and J. Köfer. 1993. Environmental factors, prevalence of pneumonia and lung lesions of slaughter swine suffering from chronic respiratory disease. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 915-921.

Backström, L. and S.E. Curtis. 1981. Housing and environmental influences on production. In Diseases of Swine. A.D. Lenman, R.D. Glock, W.L. Mengeling, R.H.C. Penny, E. Scholl and B. Straw, editors. 5th Ed. Iowa State University Press. Chapter 68. pp. 737-753.

Boon, C.R. 1992. Air quality in livestock buildings: U.K. experience and legislation. Paper 92-4043. ASAE, St. Joseph, MI.

Bundy, D.S. 1984. Rate of dust decay as affected by relative humidity, ionization and air movement. Trans ASAE. 27:865-870.

Bundy, D.S. and M.A. Veenhuizen. 1987. Dust and bacteria removal equipment for controlling particulates in swine buildings. In Latest Developments in Livestock Housing. Seminar of the 2nd Technical Section of the Commission Internationale du Génie Rural. University of Illinois. Champaign, Ill. 22-26 June, 1987. pp. 137-145.

Carpenter, G.A. 1986. Dust in livestock buildings- A review of some aspects. J. Agric. Eng Res. 33:227-241.

Castranova, V., V.A. Robinson, M.W. Barger, J.J. May, J.W. Dennis, W. Jones, M. Whitmer, P.D. Siegel and D.G. Frazer. 1992. Use of the guinea pig animal model to characterize the pulmonary response to agricultural dusts: Comparison with the reaction to the inhalation of cotton dust. 1992 Proceedings - Beltwide Cotton Conference. Memphis, Tennessee. Vol 1 pp. 251-256.

Choinière, Y. and J.A. Munroe. 1993a. Air quality inside livestock barns. OMAF factsheet 93-001. Agdex 400/717.

Choinière, Y. and J.A. Munroe. 1993b. Farm workers health problems related to air quality inside livestock barns. OMAF factsheet 93-003. Agdex 400/717.

Cowart, R.P., C.R. Boessen and J.B. Kleibenstein. 1992. Patterns associated with season and facility for atrophic rhinitis and pneumonia in slaughter swine. J. Am. Vet. Med. Assoc. 200:190-193.

Curtis, S.E. 1972. Air environment and animal performance. J. Anim. Sci. 35:628-634.

Curtis, S.E. 1987. What's up in the air? Pigs. May/June, 1987.

Curtis, S.E., C.R. Anderson, J. Simon, A.H. Jensen, D.L. Day and K.W. Kelley. 1975. Effects of aerial ammonia, hydrogen sulfide, and swine house dust on rate of gain and respiratory-tract structure in swine. J. Anim. Sci. 41:735-739.

Dawson, J.R. 1990. Minimising dust in livestock buildings. Possible alternatives to mechanical separation. J. Agric. Eng. Res. 47:235-248.

De Boer, S. and W.D. Morrison. 1988. The effects of the quality of the environment in livestock buildings on the productivity of swine and safety of humans. A Literature Review. Dept. of Animal and Poultry Science. University of Guelph, Guelph, ON.

Doig, P.A. and R.A. Willoughby. 1971. Response of swine to atmospheric ammonia and dust. J. Am. Vet. Med. Assoc. 159:1353-1361.

Donham, K.J. 1987. Human health and safety of workers in livestock housing. In: Latest Developments in Livestock Housing. Seminar of the 2nd Technical Section of the Commision du Génie Rural. 22-26 June, 1987. University of Illinois. Champaign, Ill. pp. 86-95.

Donham, K.J. 1991. Association of environmental air contaminants with disease and productivity in swine. Am. J. Vet. Res. 52:1723-1730.

Donham, K.J. and K.E. Gustafsson. 1982. Human occupational hazards from swine confinement. Ann. Am. Conf. Gov. Ind. Hyg. 2:137-142.

Donham, K.J., J.A. Merchant, D. Laisse, W.J. Popendorf and L.F. Burmeister. 1990. Preventing respiratory disease in swine confinement workers. Intervention through applied epidemiology, education and consultation. Am. J. Ind. Med. 18:241-261.

Donham, K.J., L.J. Scallon, W. Popendorf, M.W. Treuhaft and R.C. Roberts. 1986. Characterization of dusts collected from swine confinement buildings. Am. Ind. Hyg. Assoc. J. 47:404-410.

Gjerde, C., K. Ferguson, C. Mutel, K. Donham and J. Merchant. 1991. Results of an educational intervention to improve the health knowledge, attitudes and self reported behaviours of swine confinement workers. J. Rural Health. 7:278-286.

Hamilton, T.D.C., J.M Roe, F.G.R Taylor, G. Pearson and A.J.F. Webster. 1993. Aerial pollution: An exacerbating factor in atrophic rhinitis of pigs. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 895-903.

Hellickson, M.A., E.H. Schlenker, M.A. Schipull, D.P Froelich and R.R. Parry. 1989. Effects of dust and gases on labourers in livestock confinement buildings. In Proceedings of the 11th International Congress on Agricultural Engineering. Dublin, Ireland. 4-8 Sept., 1989. Vol 2. Agricultural Buildings. pp. 1471-1478.

Holness, D.L., E.L. O'Blenis, A. Sass-Kortsack, C. Pilger and J.R. Nethercott. 1987. Respiratory effects and dust exposures in hog confinement farming. Am. J. Ind. Med. 11:571-580.

Iversen, M. and H. Takai. 1990. Lung function studies in farmers during work in swine confinement units. Zbl. Arbeitsmed. Bd. 40:236-241.

Jansen, A. and J. Feddes. 1993. Effect of airborne dust on health and performance of growing pigs. Paper PNW 93-103. ASAE, St. Joseph, MI.

McQuitty, J.B. 1967. Intensive livestock farming; some of the challenges and problems. Agriculture Bulletin. Faculty of Agriculture. University of Alberta. 6:7-8.

Mercer, T.T. 1978. Respirable fraction of airborne dust: Quantitative descriptions, formal definitions and performance characteristics of samples matched to them. J. Testing and Evaluation. 6:9-19.

National Research Council of Canada. 1982. Effect of Inhaled Particles on Human Health. Influence of Particle Size and Shape. Publication no. NRCC 18564. Ottawa. ON.

Nicks, B., D. Marlier and B. Cowart. 1993. Air pollution levels in pig houses. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 635-642.

Pedersen, S. 1989. Dust and gases in livestock buildings. In Agricultural Engineering. Proceedings of the 11th International Congress on Agricultural Engineering. 4-8 Sept., 1989. Volume 2. Agricultural Buildings. pp. 1489-1494.

Phillips, P.A. 1986. Dust levels in mechanically vs naturally ventilated hog barns. Paper 86-4041. ASAE , St. Joseph, MI.

Robinson, V.A., V. Castranova, M.W. Barger and D.G. Frazer. 1992. Effect of animal weight on the response of the guinea pig model to inhalation of cotton dust. 1992 Proceedings - Beltwide Cotton Conference. Memphis, Tennessee. vol. 1 pp. 259-262.

Switzer, W.P., R.L. Engen, N.G. Goshal and J.P. Kunesh. 1981. Respiratory system. In: Diseases of Swine. A.D. Lenman, R.D. Glock, W.L. Mengeling, R.H.C. Penny, E. Scholl and B. Straw, editors. 5th Ed. Iowa State University Press. Chapter 8. pp. 138-148.

CHAPTER 2 EFFECTS OF FLOOR-APPLIED MINERAL OIL ON RESPIRABLE DUST IN A SWINE FARROWING ENVIRONMENT

INTRODUCTION

As stated in the previous chapter, evidence exists to suggest a relationship between aerosol concentration and respiratory damage in swine and humans. Therefore, it is necessary to develop effective methods to control particulate emissions in hog barns. Nicks et al. (1993) reported major variations in dust concentrations over time. They also stated that during periods of low activity, there is a greater percentage of particles between 0.5-1 μm in diameter and less particles between 1-2 and 2-5 μm than during periods of intense activity and high dust concentration. This suggests that particles in the respirable size range may continue to remain airborne even during periods of animal inactivity and that control measures may be necessary during periods of both high and low animal activity to protect respiratory health.

In addition, the composition and levels of dust may differ between various stages of swine production. Total dust concentrations were reported by Jacobson et al. (1992) to be higher in finishing units than in farrowing or grower-nursery barns. However, the concentration of respirable dust was higher in the grower-nursery units than in finishing or farrowing barns. Donham et al. (1986) reported total aerosol concentration was lowest in farrowing barns, slightly higher in grower-nursery units and highest in finishing units. However, they found respirable concentrations were highest in farrowing barns and lowest in the finishing areas. Both total dust concentrations and particle size increased from farrowing to finishing units. In addition, they reported particles in farrowing and grower-nursery units were from fecal material, while particles in the finishing units were primarily from feed. Fecal particles tend to be smaller than feed particles and will penetrate deeper into the lung (Donham et al., 1986). It may therefore be of more importance to control dust in the farrowing environment or to have different exposure limits for different production stages.

Oil as a Feed and Grain Additive

Recently, several researchers have examined the use of oils and fats as additives to swine diets to control the release of feed particulates (Chiba et al., 1985, 1987; Gast and Bundy, 1986; Gore et al., 1986; Welford et al., 1990; Xiwei et al., 1993) or grain (Wardlaw et al., 1989). By adding tallow to pig rations, Chiba et al. (1985, 1987) were able to reduce aerial dust by 21-53%. The greatest reduction occurred with addition of 7.5%

tallow, the least by adding 2.5%. By coating pellets with either fat or a fat and lignin mixture, Xiwei et al. (1993) reduced respirable dust sedimentation rate (RDSR in particles/(kg.min)) by 82-87%. RDSR was defined as the number of particles between 0.5-5 μm in size released per kg of feed per minute. Coating pellets with a fat and lignin mixture was better than the fat coating alone in reducing RDSR.

Gore et al. (1986) reduced settled dust concentrations by 45% with the addition of 5% soybean oil to starter diets. In a study to compare soybean oil, mineral oil and lecithin feed additives, Gast and Bundy (1986) found that all were able to reduce feed dustiness; however, 5% soybean oil was least effective and a mixture of both oil and lecithin was more effective than either oil or lecithin alone.

Research involving the addition of mineral oil to corn and milo was able to increase the amount of dust retained on grain kernels by 49-98% (Wardlaw et al., 1989).

Oil Application to Litter and Floors

With the evidence of dust suppressant abilities when oil is added to feeds and grain, researchers also examined the possibility of applying oil to litter in poultry barns and on floors in swine housing.

Feddes et al. (1991) studied the effects of ventilation rate and oiling litter with canola oil on particulate levels in turkey barns. They were able to reduce respirable dust concentrations by 80% with oil, whereas increasing ventilation from winter to summer rates was only able to reduce aerial contaminants by 65%. A similar study of canola oil's effectiveness showed that respirable dust concentrations were reduced by 75% when 0.15 L oil/m^2 was applied to turkey litter (Taschuk et al., 1991).

Similar reductions in dust levels have been found when oil is applied to floors in pig housing. Takai et al. (1993) reported preliminary results showing that airborne particulates could be reduced by 50-90% when 5-15 mL rapeseed oil/pig was applied to floors. Earlier work found that using 40 mL oil/m^2 could reduce airborne dust concentrations by 90% in hog barns (Takai, 1987). These results suggest that applying oil to floor surfaces may be an effective method of controlling dust levels in pig barns.

Applying oil to floors weekly, rather than daily, may be an effective means of controlling dust levels within farrowing environments where respirable dust tends to be highest, thereby reducing the amount of oil required. This thesis investigates the potential of applying mineral oil weekly, rather than daily, to the floors in

farrowing rooms as a means of dust control.

OBJECTIVES

1. To determine if applying mineral oil weekly to floors in farrowing crates is an effective means of reducing respirable dust concentrations.
2. To determine if dust suppressant activities of oil are effective for more than one week.
3. To determine if oiling floors had any effect on piglet performance.

MATERIALS AND METHODS

Facilities

The experiment was conducted from July 19-Sept. 22, 1993, under typical summer conditions at the swine unit of Agriculture Canada's Centre for Food and Animal Research, located in Nepean, ON. Three farrowing rooms, each measuring 4.8 x 11 x 2.7 m were used. Two rooms each had 5 farrowing crates measuring 1.98 x 2.08 m with a floor area of 4.12 m^2. The third room housed 6 crates, each measuring 1.63 x 2.08 m with a floor area of 3.3 m^2. Figure II-1 illustrates creep and sow areas for both types of crate. Pen floors were 1/3 solid concrete and 2/3 slatted. Sows were fed manually at 13:00 h daily. Piglets were fed creep feed *ad libitum* from 2 wks of age and weaned at approximately 28 d of age. Piglets were ear notched for identification, received iron injections and their teeth and tails were clipped on the day of birth. Male piglets were castrated at 11 d of age.

The barn was ventilated by a filtered-air, positive-pressure ventilation system. Two inlets, each measuring 24 x 48 cm, supplied air to each of the rooms. Air was passively exhausted at the opposite end of the room. Inlet and exhaust openings could be controlled to provide similar ventilation rate (L/s) in each room. Fluorescent lighting was provided in each room. Lights were regulated by automatic timers and were on from 06:00-22:00 h daily.

Farrowing rooms were managed on an all-in all-out basis. The day following weaning, crates were dismantled and the room cleaned and disinfected. When possible, the room stood empty for one week before being used again.

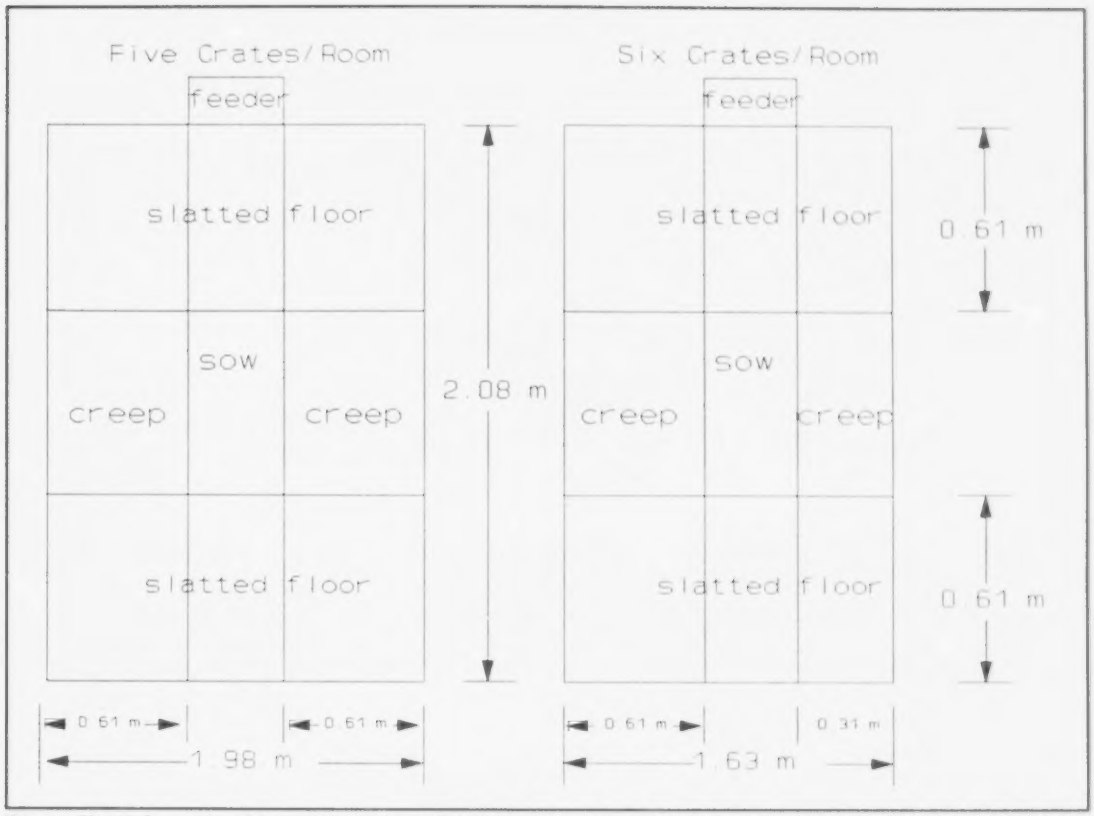

Figure II-1 Schematic of farrowing crates illustrating crate size differences for rooms with 5 or 6 crates/room

Experimental Design

The experiment was designed with 3 treatments and 2 replicates per treatment. Treatments were monitored for 3 weeks and were as follows:

Control Application	no oil applied
Weekly Application	oil was applied once per week for 3 weeks
Single Application	oil applied once at the beginning of week one to determine the length of dust suppression

Treatments were randomly assigned to the rooms with the proviso that all treatments were repeated twice and that no room received the same treatment. Table II-1 presents the order of treatments.

A minimum of 4 and maximum of 5 sows were required for each treatment and a total of 28 sows and 281 piglets were used in the experiment. A group of sows was moved into the farrowing room approximately one week before farrowing. Only one room was filled per week and was occupied for approximately 5 wks.

Table II-1 Order of oil applications

REPLICATE	*ROOM A*	*ROOM B*	*ROOM C*
1	single	control	weekly
2	control	weekly	single

Therefore, treatments were not completed during the same 3-wk period. Figure II-2 shows the weeks of monitoring for each treatment. During the week before farrowing, no treatments were applied in order to allow dust concentrations to build. Treatments began on the Monday after at least 4 sows in a room had farrowed.

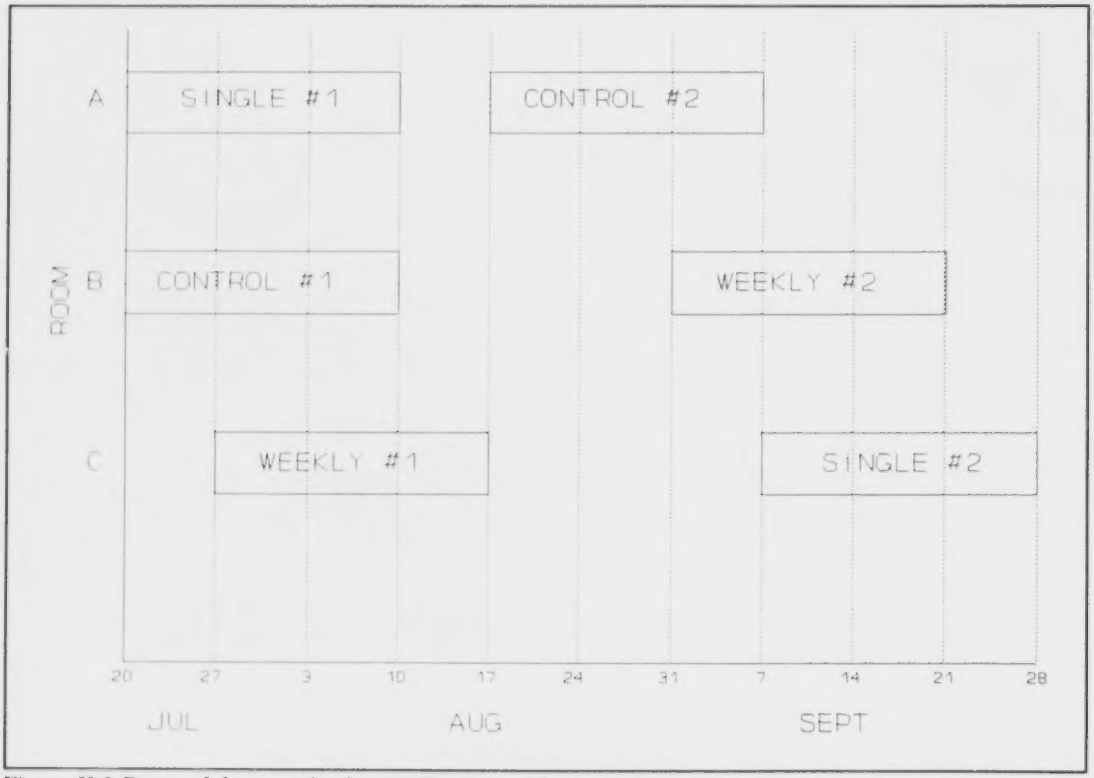

Figure II-2 Dates of dust monitoring, replicates 1 and 2

Oil was applied between 09:00-10:00. Dust concentrations were monitored for a 24-h period, beginning 24 h after oil application. Ventilation rate was measured before and after the dust monitoring period. Maximum, minimum, wet and dry-bulb temperatures were recorded the day of oil application and before and

after the 24-h dust monitoring period (see Table II-2).

Table II-2 Weekly schedule of events for control, weekly and single oil applications

WEEK	*DAY ONE*	*DAY TWO*	*DAY THREE*
1[a]	temperatures recorded	temps and ventilation rate recorded	dust monitoring completed
	exhaust screens washed	24 h dust monitoring begins	temps and ventilation rate recorded
	oil applied to floors [•]		piglets weighed

[•] oil is applied in weekly and single treatments only
[a] Weeks 2 and 3 are similar to week 1 except that oil is not applied to floors in the control or single treatments.

Piglets were also weighed after completion of the 24-h dust monitoring period. Details of sampling techniques are presented in later sections.

Oil Application

Mineral oil (Vetoquinol Canada Inc., Jolliet, Que.) was applied to floors using low-pressure hand operated plant misters (Continental Industries, Brampton, ON). Five sprayers were each filled with an allotment of oil to be applied to one crate floor. The initial allotment was 250 mL/crate in rooms with 5 crates/room and 207 mL/crate in the room with 6 crates/room (see appendix for calculations). Oil was measured using a graduated cylinder. A coarse mist of oil was applied under low pressure to prevent dispersing oil droplets of respirable size. Oil was applied to all floor surfaces, slatted and concrete, and was applied in both the sow and piglet areas. Sows were standing during oil application and oil was applied underneath them. To avoid applying oil on the piglets, they were moved to one creep area and oil was applied to the opposite side. The procedure was repeated for the other creep area. In order to maintain a similar amount of oil applied/room, oil was applied in both occupied and unoccupied crates.

During the first replicate, it was noticed that piglets consumed small amounts of oil from the floor. Mineral oil acts as a laxative and piglets on the weekly treatment developed scours in a pattern similar to that of oil application. In order to prevent piglets from consuming the oil, the application rate was reduced to 24

mL/m^2 in the second replicate of both the single and weekly treatments, (100 mL/crate, 5 crates/room, 81 mL/crate, 6 crates/room, see appendix for determination of these rates). In addition, applying oil to the floors in the sow area rendered the surface noticeably slippery for the sow. In order to provide stable footing during the second replicate, oil was applied over the sow, rather than on the floor. These modifications eliminated the problems.

Dust Monitoring

Dust concentrations were monitored once a week as shown in Table II-2. Dust was monitored continuously for a 24-h period once a week, 24 h after oil was applied. A remote sampling technique was used so that rooms could be monitored sequentially and to keep sampling equipment clean. Sampling equipment was housed in a plywood box supplied with filtered air, located in the hallway outside the rooms. Room air was drawn through transparent, flexible Nalgene tubing with a 1.4 cm external diameter and a 0.6 cm internal diameter. These tubes, located 92 cm above the crate floor, (Figure II-3) ran from the centre of each room into the hallway, where they were connected to a ball valve unit. The length of tubing (17.7 m) was the same for all 3 rooms. The ball valve assembly was also connected to a forward light-scattering particle counter (Climet Instruments, Redlands, CA). This particle counter counted particles according to their size, rather than their mass. As particles pass through the light beam in the instrument, light is scattered and detected by a sensor. The amount of light scattered is proportional to the size of the particle passing through the light beam.

Samples were drawn from the rooms to the particle counter through the tubing and particle counts were stored on a computer and transferred to diskette at the end of the monitoring period. The number of particles >0.5 μm diameter per 0.01 cubic foot of air was counted every 36 s. This count was multiplied by 0.00353 to obtain the particle concentration in particles/mL (see appendix for determination of conversion factor). Four 36-s samples were collected from each room once every half hour. For the remainder of the half hour, air from the hallway was sampled. Sampling equipment was checked weekly to ensure proper function. To prepare data for analysis, the first reading from each room and all readings from the hallway were removed from the data set. The first reading from each room was discarded as there was an 8-12 s delay as particles travelled along the sampling tube. In addition, pressure changes that occur during valve opening and closing may also have affected

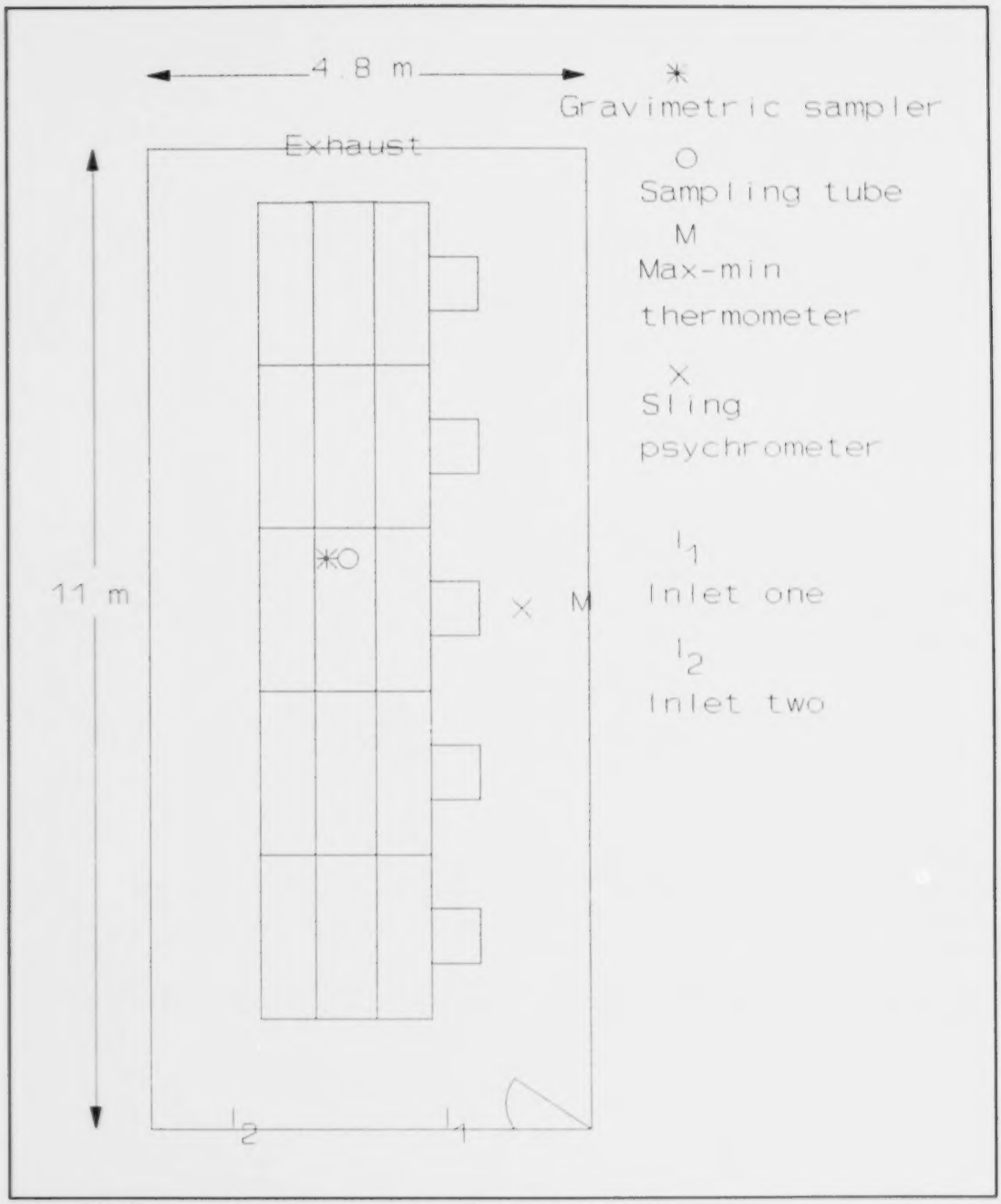

Figure II-3 Diagram of farrowing room and sampling locations

the first reading collected. Data were scanned for errors caused by mechanical problems and these values were removed.

Temperature Monitoring

Maximum (T_{max}), minimum (T_{min}), wet-bulb (T_{wb}), and dry-bulb (T_{db}) temperatures were measured in each farrowing room. Maximum and minimum temperatures were measured with a maximum-minimum thermometer (Taylor Instruments, Toronto, ON), hung 1.6 m from the floor, along the centre of the wall closest to the sow feeders (Figure II-3). Thermometers were reset immediately after the temperatures were recorded. Wet and dry-bulb temperatures were measured with a sling psychrometer (Taylor Instruments, Rochester, NY). Measurements were taken in the feed alley, near the max-min thermometer. The wick was wetted with water prior to monitoring each room, and the psychrometer was whirled for approximately 70 s. Wet-bulb temperature was read immediately to prevent the reading from deviating once rotations were stopped. Wet and dry-bulb temperatures were recorded in Fahrenheit (°F) and converted to Celsius (°C) by equation (II-1):

$$C = F \times 0.56 - 17.8 \qquad \text{(II-1)}$$

where:
C= degrees Celsius
F= degrees Farenheit
Curtis, (1987)

All temperatures were recorded between 09:00-09:30 on day 1 and 2. On day 3 however, they were not recorded until dust sampling was completed, usually between 11:00-12:00.

Ventilation Rate

To measure room ventilation rate, a removable styrofoam duct was constructed to fit over the inlets based on a design by Jorgenson (1983). Internal dimensions of the duct were 24 x 48 cm and it was 240 cm in length. Five 1.3 cm diameter holes for velocity measurements were equally spaced vertically along one 24 cm side, 204 cm from the end of the duct (see Figure II-4). The duct was held over inlet 2 (see Figure II-3), flush with the wall and parallel to the floor by 2 assistants while air speed sampling took place. Air velocity was measured using a thermal anemometer (Velocicalc, TSI, St. Paul, MN) at 25 points on a 5x5 grid within the duct. The average of these points (m/s) was recorded and total ventilation rate (L/s) was calculated using equation (II-2).

The equation includes a factor of 2 as there were 2 inlets/room. Inlet 1 was not measured, because the water line to the farrowing crates prevented proper positioning of the duct. Preliminary data suggested that air

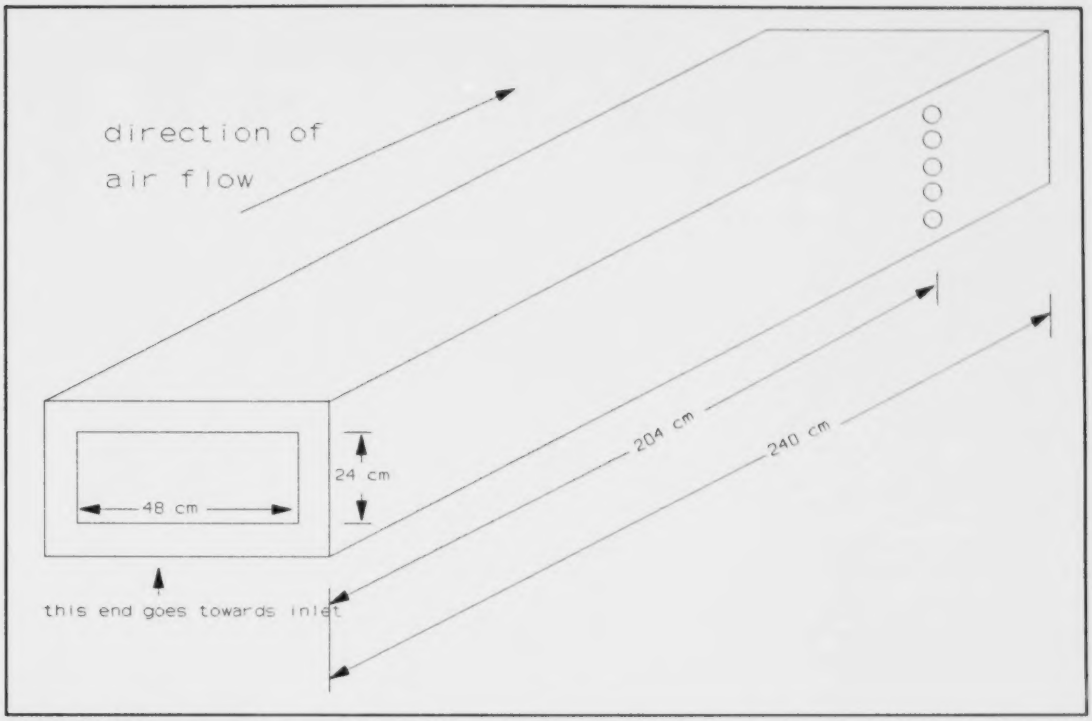

Figure II-4 Diagram of duct used to monitor ventilation rate

$$VR = V \times 0.1152 \times 1000 \times 2 \qquad \textbf{(II-2)}$$

where:
VR= total ventilation rate (L/s)
V= average measured air velocity (m/s)
0.1152= *cross sectional area of duct* (m^2)
1000= *conversion factor* m^3/s - *L/s*

velocity from both inlets was approximately the same.

Ventilation rate was expected to be lowest in room C. Therefore, this room was measured first and the ventilation rate in the other 2 rooms was adjusted to a similar rate. Air velocities were recorded twice weekly, before and after the 24-h dust monitoring period.

To ensure effective ventilation in the experimental rooms, screens over the exhaust outlets were removed and pressure washed weekly to remove dust buildup. This was done on the day oil was applied to floors.

Piglet Weights

The number of sows and piglets/room was recorded weekly, after the 24-h dust monitoring period. Piglets were weighed to calculate the total piglet mass/room and the average piglet mass. Records were kept

for each sow and litter, and piglets were weighed in batches. Several piglets were placed on the scale, the weight and number of piglets on the scale were recorded. The scale was zeroed between batches. The procedure was repeated for all litters in the room. Sow and litter numbers and the date of birth were recorded, as well as date weighed. Data for each room were summarized in a spreadsheet (Lotus 1-2-3) and included total number of piglets and sows, total piglet mass, average piglet mass and average piglet age in days, as well as the replicate, treatment, week and room numbers.

Statistical Analysis

Piglet data were classified by replicate, treatment, room and week. Data were analyzed using analysis of variance. The model for analysis of total and average piglet mass and age included replicate (1 d.f.), week (2 d.f.), treatment (2 d.f.), room (2 d.f.) and treatment by week interaction (4 d.f.).

Least squares means and standard errors were calculated for dust levels, temperatures, ventilation rates and piglet mass. Means were separated using Duncan's New Multiple Range test (α = 0.05). Computations were made using SAS (1989, SAS Institute, Cary, NC).

RESULTS

Dust

Figures II-5 to II-7 illustrate the dust concentrations measured during weeks 1, 2 and 3, respectively. Several important trends can be seen. During week 1 (Figure II-5), particle concentrations in the single and weekly treatments were quite similar and were lower than control levels. This similarity between treatments was expected. During the first week, the treatments were identical and suppressant activities of the oil should be the same. During week 2 (Figure II-6) however, treatments differ. In the first replicate, levels in the single treatment returned to levels equivalent to or higher than the control treatment. This trend was not seen in the second replicate. With the exception of levels between the hours of 08:00-09:30, dust levels were lower than the control and were quite similar to levels in the weekly treatment. A reversal was seen in the third week (Figure II-7). Levels in the single treatment of replicate 1 were lower than the control and the reverse was seen in replicate 2. From these results, it was difficult to determine if dust-suppressant capabilities last more than one week. Monitoring dust more frequently than once a week may aid in determining this.

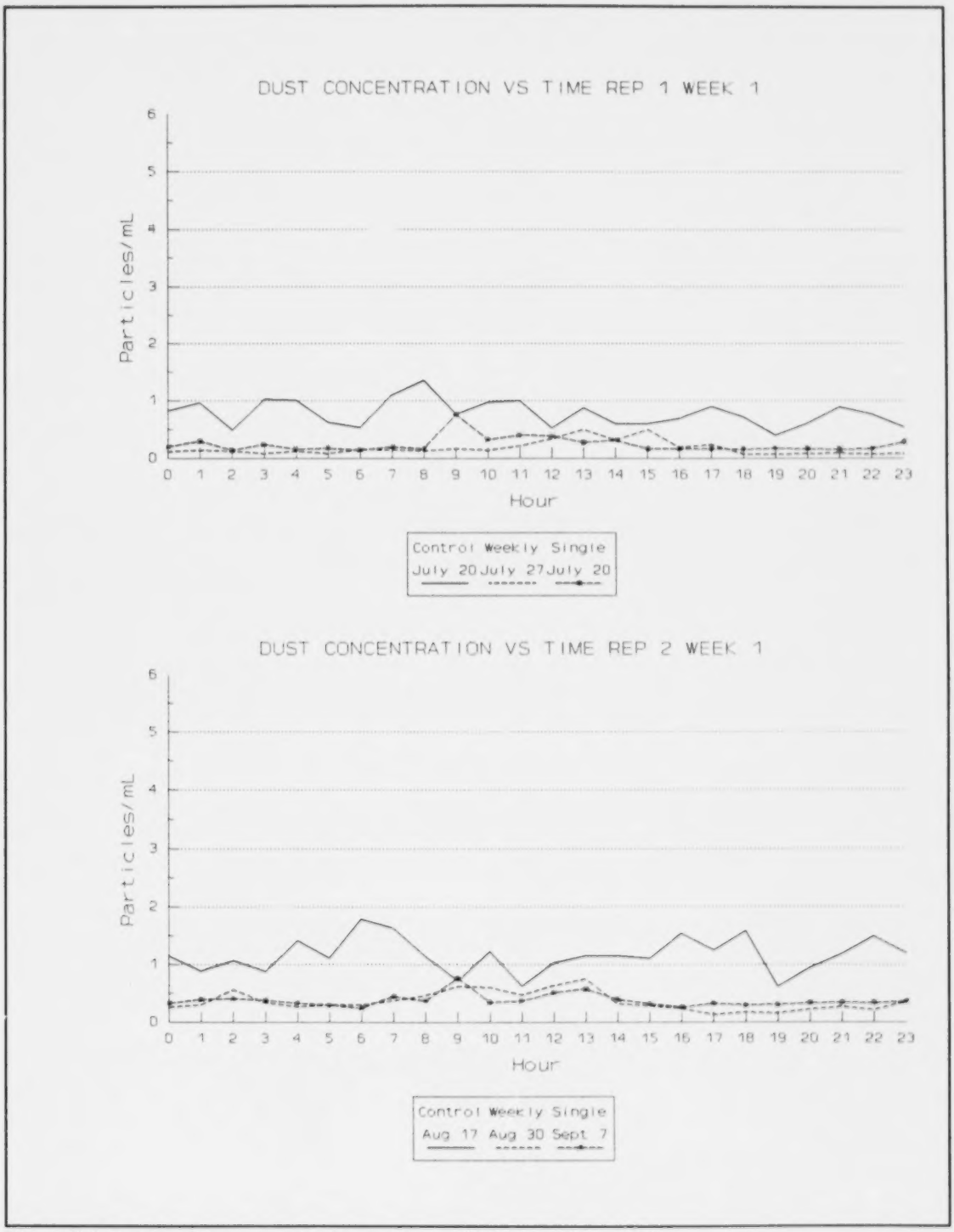

Figure II-5 Graphs of dust concentration vs time, replicates 1 and 2 week 1

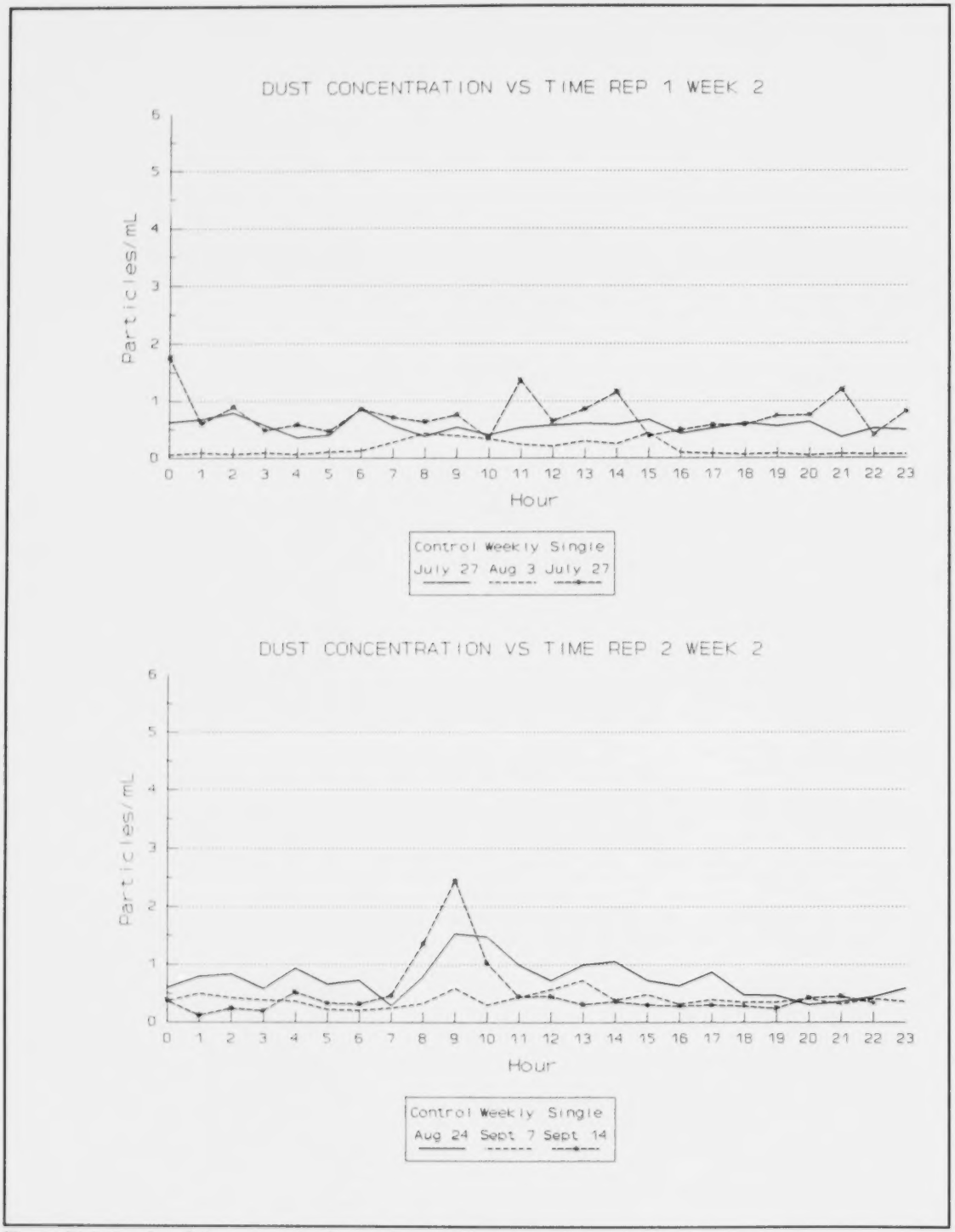
DUST CONCENTRATION VS TIME REP 1 WEEK 2
Particles/mL
0 1 2 3 4 5 6
Hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Control Weekly Single
July 27 Aug 3 July 27
DUST CONCENTRATION VS TIME REP 2 WEEK 2
Particles/mL
0 1 2 3 4 5 6
Hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Control Weekly Single
Aug 24 Sept 7 Sept 14

Figure II-6 Graphs of dust concentration vs time, replicates 1 and 2 week 2

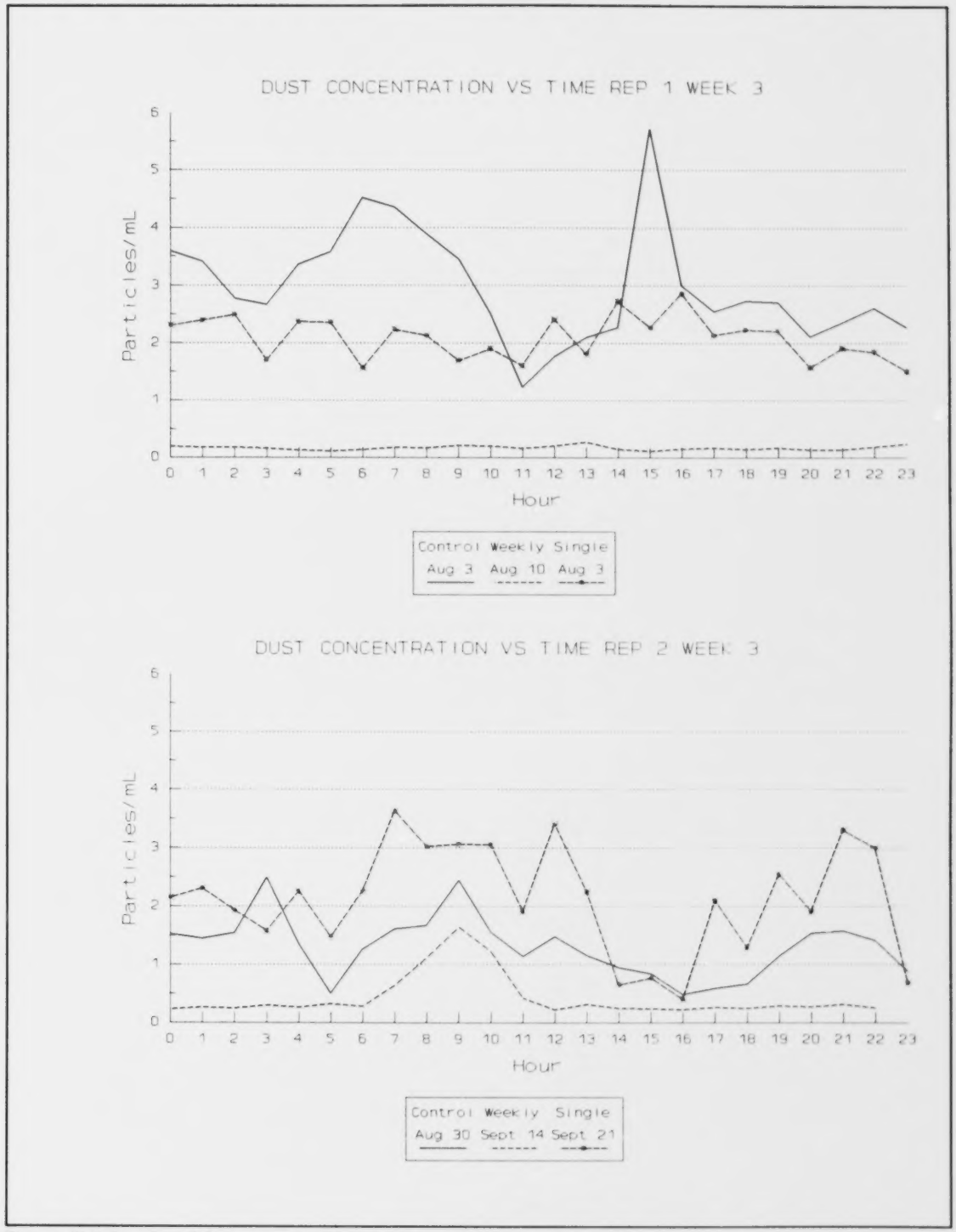
DUST CONCENTRATION VS TIME REP 1 WEEK 3
Particles/mL
0 1 2 3 4 5 6
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour
Control Weekly Single
Aug 3 Aug 10 Aug 3
DUST CONCENTRATION VS TIME REP 2 WEEK 3
Particles/mL
0 1 2 3 4 5 6
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour
Control Weekly Single
Aug 30 Sept 14 Sept 21

Figure II-7 Graphs of dust concentration vs time, replicates 1 and 2 week 3

From these graphs, it is apparent that applying mineral oil weekly was able to keep dust concentrations low during the day after oil application. A second monitoring period later in the week would indicate whether particulate concentrations remained low throughout the week.

Comparing dust levels across weeks, there was an increase in dust with time for all treatments (Table II-3). The greatest increase occurred between weeks 2 and 3. There may be several reasons for this trend. Piglet growth rate tended to follow a linear trend in weeks 1-2. However, during weeks 2-3, the growth rate increased (see Figure II-8). This rapid growth increase may play a role in increased particle levels. In addition, there was a buildup of feed and feces over time. Feed alleys and the crate tops were cleaned once a week but pen floors were not, to prevent oil from being removed from the floors. The accumulated feces and feed may have also contributed to increased dust concentrations with time.

Table II-3 Mean dust concentrations (particles/mL) by week, control, weekly and single mineral oil applications

TREATMENT	*WEEK 1*	*WEEK 2*	*WEEK 3*
Control	0.97	0.65	2.14
Weekly	0.26	0.27	0.29
Single	0.30	0.63	2.10

SEM = 0.07 in all cases.

Temperature

All temperatures were higher in replicate 1, except for T_{max}. Outdoor temperatures and relative humidities were higher during the first replicate. This may have influenced the barn environment and led to the higher indoor temperatures. T_{min} and T_{db} were slightly higher on the third day (T_{min}=23, 24 and 25 and T_{db}=26, 27 and 28, days 1, 2 and 3, respectively). As mentioned previously, temperatures on day 3 were recorded later in the day than on day 1 or 2. Temperatures were measured closer to the hottest period of the day and are expected to be higher. T_{wb} however was highest on day 2 (20.5, 22.3 and 21.5, days 1, 2 and 3, respectively). The reason for this is unclear.

Mean values for T_{max}, T_{min}, T_{wb} and T_{db} are presented in Table II-4 and as seen in the table, T_{max}

was highest in the weekly treatment. Ventilation rate tended to be lowest in this treatment (see the next section) and therefore, temperatures may be expected to be slightly higher. T_{min}, T_{wb} and T_{db} were all highest in the control treatment. The reason for this is unclear. In most cases, day to day variation in temperatures within weeks is very small. Often, means were different by only 1-2 °C. They are not expected to influence the other parameters measured.

Table II-4 Summary of mean temperatures (°C) by treatment

TREATMENT	T_{max}	T_{min}	T_{wb}	T_{db}
Control	28.0 (0.29)	25.6 (0.29)	22.5 (0.39)	28.0 (0.34)
Weekly	29.0 (0.28)	23.8 (0.28)	21.7 (0.39)	27.5 (0.34)
Single	27.7 (0.28)	23.0 (0.28)	20.2 (0.39)	26.0 (0.34)

SEM in parentheses

Ventilation Rate

Ventilation rate tended to be higher before dust monitoring than afterwards with mean ventilation rates of 276 and 256 L/s being recorded on days 2 and 3, respectively. This decrease in ventilation was expected since, as mentioned previously, screens on the exhaust openings were removed and washed weekly on day 1. By day 3 dust had accumulated on these screens and may have affected ventilation efficiency, resulting in the observed decrease.

Table II-5 Summary of mean weekly and overall ventilation rates (in L/s) for control, weekly and single oil applications

TREATMENT	*WEEK 1*	*WEEK 2*	*WEEK 3*	*OVERALL*
Control	270	263	278	270
Weekly	236	268	267	257
Single	291	253	268	271

Table II-5 presents mean weekly and overall ventilation rates by treatment. Mean ventilation rates tended to be lowest in the weekly treatment (mean rates were 270, 257 and 270 L/s, for control, weekly and single treatments, respectively). As well, room A tended to have the highest rate (mean rates were 272, 259 and 266 L/s, for rooms A, B and C, respectively). The overall mean ventilation rate was 266 L/s.

Piglet Weights

Figure II-8 illustrates the piglet growth curve. The curve is exponential between days 0-30, with the sharpest increase occurring from days 15-30. Average piglet mass was not significantly different by treatment ($p=0.14$). Mean piglet mass was 3.6 kg for both the control and weekly treatments and 4.1 kg for the single treatment. Mean piglet age was 15 and 13 days, for replicates 1 and 2, respectively.

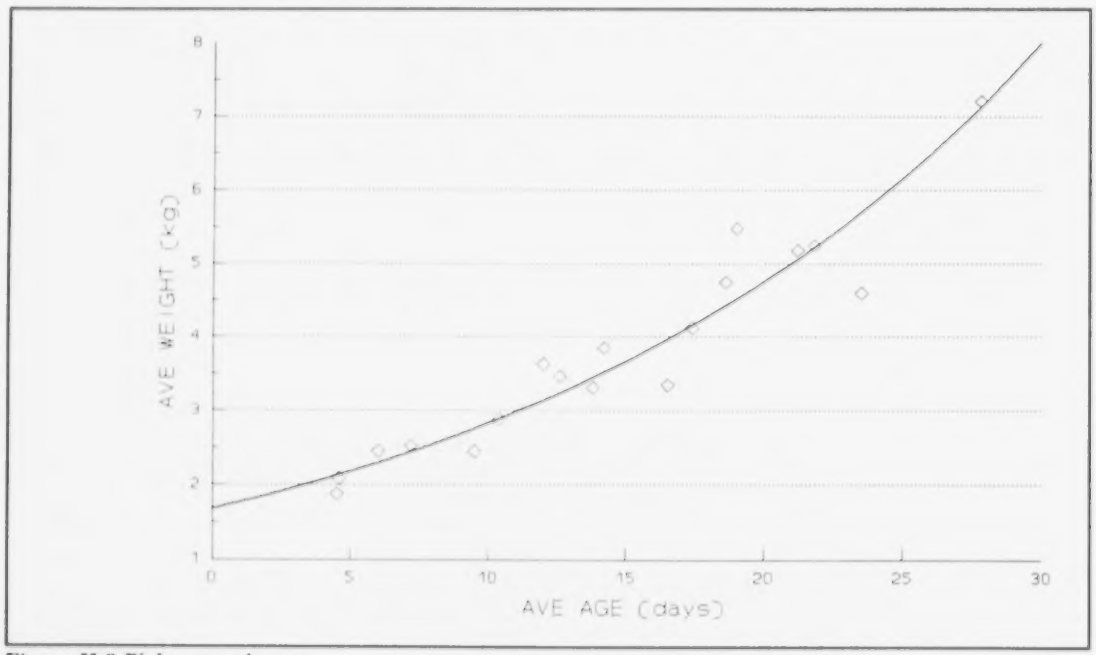

Figure II-8 Piglet growth curve

Table II-6 Mean total piglet mass (kg), average piglet mass (kg) and average piglet age (d), summarized by week and treatment

VARIABLE	*CONTROL*	*WEEKLY*	*SINGLE*
TOTAL PIGLET MASS			
Week 1	110 (3.6)	102 (1.7)	118 (39.2)
Week 2	171 (2.8)	141 (0.7)	195 (47.8)
Week 3	230 (3.9)	195 (3.2)	270 (56.2)
AVERAGE PIGLET MASS			
Week 1	2.3 (0.31)	2.5 (0.001)	2.6 (1.0)
Week 2	3.7 (0.27)	3.5 (0.20)	4.1 (1.7)
Week 3	5.0 (0.31)	5.0 (0.63)	5.7 (2.2)
AVERAGE PIGLET AGE			
Week 1	5.9 (1.8)	7.8 (2.5)	9.2 (6.6)
Week 2	13.4 (1.1)	14.3 (3.2)	16.1 (8.1)
Week 3	19.9 (1.8)	21.3 (3.2)	22.6 (7.4)

SEM in parentheses

DISCUSSION

Mean dust concentrations for the treatments studied were 1.25, 0.28 and 1.01 particles/mL for control, weekly and single applications, respectively. During the third week of study when dust was highest, particle concentrations ranged from 0.14-5.72 particles/mL. These concentrations are low when compared to literature values. Clark and McQuitty (1988) reported mean respirable dust concentrations ranging from 1.1 to 7.0 particles/mL in various types of swine units. A review by DeBoer and Morrison (1988) reported mean area respirable dust concentrations in hog barns ranging 0.2-0.53 mg/m^3. For purposes of comparison, 1 mg/m^3 is approximately equal to 100 particles/mL (Choinière and Munroe, 1993). Meyer and Manbeck (1986) measured total and respirable dust concentrations in several production units. They reported a respirable dust concentration of 1.36 mg/m^3 in a barn monitored in March. Dust level in May was 0.2 mg/m^3. They also reported that between 45 to 81% of total dust was respirable.

In this study, dust concentrations were sampled remotely through 17.7 m of tubing. It was hypothesized that using this sampling technique resulted in artificially low dust concentrations. Preliminary work with various lengths of tubing confirmed this hypothesis. Therefore, an experiment was designed to quantify this effect. The following chapter will describe the experiment and results. Adjusted dust concentrations will be presented, compared to the literature values and discussed in a later chapter.

REFERENCES

Chiba, L.I., E.R. Peo, Jr., A.J. Lewis, M.C. Brumm, R.D. Fritschen and J.D. Crenshaw. 1985. Effect of dietary fat on pig performance and dust levels in modified open front and environmentally regulated confinement buildings. J. Anim. Sci. 64:763-781.

Chiba, L.I., E.R. Peo, Jr. and A.J. Lewis. 1987. Use of dietary fat to reduce dust, aerial ammonia and bacterial colony forming particle concentrations in swine confinement buildings. Trans ASAE 30:464-468.

Choinière, Y. and J.A. Munroe. 1993. Air quality inside livestock barns. OMAF factsheet 93-001. Agdex 400/717.

Clark, P.C. and J.B. McQuitty. 1988. Air quality in farrowing barns. Can. Agric. Eng. 30:173-178.

Curtis, S.E. 1981. Environmental Management in Animal Agriculture. Iowa State University Press. Ames, Iowa. p 410.

DeBoer, S. and W.D. Morrison. 1988. The effects of the quality of the environment in livestock buildings on the productivity of swine and safety of humans. A Literature Review. Dept. of Animal and Poultry Science. University of Guelph. Guelph ON.

Donham, K.J., L.J. Scallon, W. Popendorf, M.W. Treuhaft and R.C. Roberts. 1986. Characterization of dusts collected from swine confinement buildings. Am. Ind. Hyg. Assoc. J. 47:404-410.

Feddes, J.J.R., K. Taschuk, F.E. Robinson and C. Riddell. 1991. Effect of ventilation rate and oiled litter on air quality, health and performance of heavy tom turkeys. Paper 91-4578. ASAE, St. Joseph, MI.

Gast, R.M and D.S. Bundy. 1986. Control of feed dusts by adding oils. Paper 86-4039. ASAE, St. Joseph, MI.

Gore, A.M., E.T. Kornegay and H.P. Veit. 1986. The effects of soybean oil on nursery air quality and performance of weanling pigs. J. Anim. Sci. 63:1-7.

Jacobson, L.D., K.A. [illegible]ni, P.E. Arellano and C.J. Pijoan. 1992. Winter swine ventilation evaluation using air quality criteria. Paper 92-4039. ASAE, St. Joseph, MI.

Jorgenson, R. 1983. Fan testing. In Fan Engineering: An Engineer's Handbook on Fans and Their Applications. 8th edition. Buffalo Forge Co. Buffalo, NY. chapter 13 p. 13-4.

Meyer, D.J. and H.B. Manbeck. 1986. Dust levels in mechanically ventilated swine barns. Paper 86-4042. ASAE, St. Joseph, MI.

Nicks, B., D. Malier and B. Canart. 1993. Air pollution levels in pig houses. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 635-642.

Takai, H. 1987. Minimise dust by spraying oil emulsion. Pigs. May/June 1987. p.13.

Takai, H., F. Møller, M. Iversen, S.E. Jorsal and V. Bille-Hansen. 1993. Dust control in swine buildings by spraying of rapeseed oil. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 726-733.

Taschuk, K., J.J.R. Feddes, F.E. Robinson and C. Riddell. 1991. Effect of oiled litter on air quality health and

performance of heavy tom turkeys. Paper 91-224. CSAE, Saskatoon, SK.

Wardlaw, H.D. Jr., C.B. Parnell Jr. and B.J. Lisikar. 1989. Dust suppression results with mineral oil applications for corn and milo. Trans ASAE 32:1770-1726.

Welford, R.A., J.J.R. Feddes and E.M. Barber. 1992. Pig building dustiness as affected by canola oil in the feed. Can. Agric. Eng. 34:365-373.

Xiwei, Li, J.E. Owens, A.J. Murdoch and C.C. Pearson. 1993. Respirable dust from animal feeds. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 747-753.

CHAPTER 3 EFFECTS OF TUBING LENGTH ON PARTICLE COUNTS

INTRODUCTION

During the first several weeks of study, unexpectedly low particle concentrations were observed using the dust sampling methodology described in the previous chapter. However, when the particle counter was sampling from the rooms directly (i.e. without tubing to obtain the air sample), particle concentrations corresponding to expected levels were obtained. A similar remote sampling technique has been used by several researchers (Perkins et al., 1993; Zuidhof et al., 1993; Feddes et al., 1991; Taschuk et al., 1991). However, all of these studies used a type of sampling tube different to the one used in this study and dust concentration in those studies was not affected by the sampling technique (Feddes, 1993, personal communication). Preliminary work comparing direct vs indirect sampling in this particular situation suggested that indirect sampling through 17.7 m of tubing resulted in particle counts that were approximately one third of those obtained by direct aerosol sampling. As well, it suggested a linear relationship between length of tubing and dust reduction. On the basis of this preliminary work on experiment was designed to quantify this effect.

OBJECTIVES

1. To determine and quantify the effect that sampling through different lengths of tubing had on observed dust levels.
2. To formulate an adjustment factor so that results from the application of mineral oil could be adjusted for this effect and compared to literature values.

MATERIALS AND METHODS

Experimental Design

To quantify the effects of tubing length on particle count, a 5 x 5 Latin square was designed. Five lengths of tubing (0, 4.6, 9.2, 13.8 and 18.4 m) were used. The order of treatments is presented in Table III-1.

The square was repeated at 08:30 and 10:00 on 2 consecutive days, yielding 4 replicates of the square and 20 observations for each length of tubing. All replicates were carried out in the same room.

Facilities and Equipment

One room, containing 6 farrowing crates was used. A detailed description of the room is presented in

Table III-1 Order of treatments for 5 x 5 Latin square

	ORDER				
TIME PERIOD	***1***	***2***	***3***	***4***	***5***
1	4.6 m	13.8	0	9.2	18.4
2	13.8	4.6	18.4	0	9.2
3	0	9.2	4.6	18.4	13.8
4	9.2	18.4	13.8	4.6	0
5	18.4	0	9.2	13.8	4.6

the previous chapter. Five sows and litters (ave piglet age 23 d) were in the room when the experiment was conducted.

The particle counter (described in chapter 2) was placed in the room close to the location of the sampling tube, but was not connected to the ball valve unit and counts were recorded manually rather than by computer. The number of particles > 0.5 μm in diameter per 0.01 cubic foot of air were counted as in the previous study. Counts were not converted to particles/mL.

Experimental Protocol

Upon completion of the previous study, the sampling tube was removed from the hallway and room and cut into 4 sections, each measuring 4.6 m in length. These sections were each suspended within the room so that one end could be connected to the adjacent section of hose, and the opposite end could be connected to the dust monitoring equipment without having to move the dust sampler. The various lengths of tubing used were formed by joining the 4.6 m sections together (i.e. 4 sections were joined to make 18.4 m). Sections were joined by inserting the ends of sampling tube into a 5 cm section of rubber hose. Ends of the sampling tube were positioned flush with each other to simulate an uncut tube. Dust concentration was measured 0.92 m from the floor in the centre of the room as in the previous study.

The required length of tubing was connected to the particle counter and an assistant initialized the dust count by pressing the START button on the particle counter. The first particle count was not recorded, as there is an 8-12 s delay for particles to travel through the maximum length of tube. The second count was recorded

manually on a data sheet by the assistant, the new length of tube connected, and the procedure repeated from the initialization of the sampler. An attempt was made to keep animal activity at a constant level within each time period. If a nursing episode began part way through a time period, dust levels were allowed to return to previous levels before continuing with sampling. However, activity is not the same within columns or within squares.

Once sampling was completed, dust recovery rates were calculated for all lengths within each row. The count obtained at 0 m of tubing was assumed to be the true dust concentration for the row. Percent dust recovery was calculated using equation (III-1).

$$R=\frac{x}{c}\times 100 \qquad \text{(III-1)}$$

where:
R=Percent Recovery
x=Particle Count at x meters
c=Particle Count at 0 meters

Using this formula, percent recovery was 100% when no tubing was used.

Statistical Analysis

Data were analyzed using analysis of variance. Sources of variation were: replicate (3 d.f.), time(replicate) (16 d.f.), order (4 d.f.), linear effect of length (1 d.f.), remaining variation due to length (3 d.f.) and replicate by length interaction (12 d.f.). The linear effect represents the linear regression of percent recovery on tubing length. Data were analyzed using SAS (1989, SAS Institute, Cary, NC).

RESULTS

The linear effect of tubing was significant (p=0.0). Figure III-1 illustrates the linear relationship between dust recovery and tubing length. Percent recovery at 4.6 m was greater than 100% as dust levels at this length occasionally exceeded dust levels recorded with no tubing. Mean percent recovery at 18.4 m was 38.5% (see Table III-2). This means that the particle counts sampled through this length of tubing were 38.5% of what they would have been if no tubing was connected to the sampling equipment. For this reason, dust levels in the previous study were artificially low. An adjustment factor was calculated for 17.7 m of tubing by substituting 17.7 in for L in the regression equation in Figure III-1, where P is equal to the percent recovery. Therefore, hourly

means obtained in the previous experiment involving mineral oil were adjusted according to equation (III-2) in order to compare them to literature values.

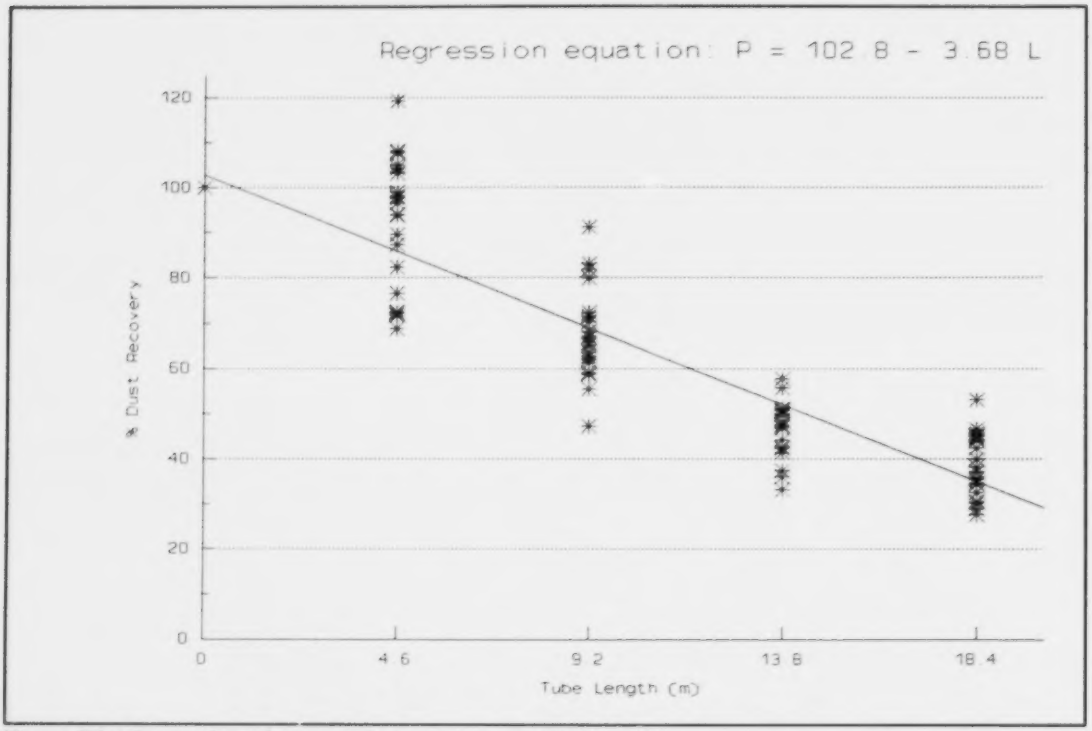

Figure III-1 Regression of percent dust recovery on tube length

Table III-2 Mean percent dust recovery for various lengths of tubing

LENGTH (m)	*MEAN RECOVERY (%)*	*STANDARD DEVIATION*	*RANGE*
0	100	0	-
4.6	92.3	14.3	69-119
9.2	67.8	10.4	47-91
13.8	45.8	7.0	33-58
18.4	38.5	7.0	28-53

$$x = \frac{c}{0.38} \qquad \text{(III-2)}$$

where:
c=*Particle concentration at* 17.7 *m*
x=*Particle concentration at* 0.0 *m*

DISCUSSION

The reason for the reduction in dust concentrations when sampling through a long length of tube is unclear. As mentioned previously, this effect was not observed in other studies using a similar remote dust sampling technique. The effects observed in this experiment may be unique to the type of sampling tube used in this study. Although the exact nature of dust reduction is unknown, there are several possible explanations.

The particular type of tubing used may have developed an electrostatic charge along the internal surface. As particles are drawn through the tube, some may adhere to the inner walls of the tube, resulting in lower particle counts. Also, during some preliminary work for the experiment involving mineral oil, there was an equipment failure involving the pump used to draw air samples to the particle counter. The pump was repaired and restored to working condition. However, sampling through a long section of tube such as was used in these experiments may have influenced the working efficiency of the air pump in the dust sampler. This may also have led to the observed effect.

Even though the reason for this reduction is unclear, the effect appears to be consistent and was quantified. In order to compare the results of the experiment involving mineral oil to those obtained by other researchers, the dust levels presented in the previous chapter were subsequently adjusted for the effects of tubing illustrated in this study and these results are presented and discussed in the following chapter.

CONCLUSIONS

1. As the length of sampling tube increases, percent dust recovery decreases. Mean percent recovery was 38.5% using 18.4 m of tube.
2. The reason for the observed effect was unclear and was believed to be unique to the type of tubing used in this study. Possible explanations for the effect include an electrostatic charge along the inside of the tube or a long section of tube overwhelming the air pump on the particle counter.
3. Particle levels in chapter 2 were assumed to be artificially low as a result of sampling technique.

Therefore, these levels were divided by 0.38 to adjust for this effect.

REFERENCES

Feddes, J.J.R., K. Taschuk, F.E. Robinson and C. Riddell. 1991. Effect of ventilation rate and oiled litter on air quality, health and performance of heavy tom turkeys. Paper 91-4578. ASAE, St. Joseph, MI.

Perkins, S.L., M.J. Zuidhof, J.J.R. Feddes and F.E. Robinson. 1993. The effect of stocking density on air quality and the health and performance of heavy tom turkeys. Unpublished data. To be submitted to J. Appl. Poultry Res.

Taschuk, K. J.J.R. Feddes, F.E. Robinson and C. Riddell. 1991. Effect of oiled litter on air quality health and performance of heavy tom turkeys. Paper 91-224. CSAE, Saskatoon, SK.

Zuidhof, M.J., J.J.R. Feddes, F.E. Robinson and C. Riddell. 1993. Effect of ventilation rat and stocking density on turkey health and performance. J. Appl. Poultry Res. 2:123-129.

CHAPTER 4 PRESENTATION OF ADJUSTED PARTICLE LEVELS AND DISCUSSION

INTRODUCTION

As shown in chapter 3, sampling through 17.7 m of tubing significantly affected the particle levels obtained in the experiment involving floor-applied mineral oil. Although the reason for the observed effect is unknown, it is clear that the recorded dust values presented in chapter 2 were lower than the actual particle concentrations in the rooms. In addition, the dust data in chapter 2 were lower than other dust levels in swine units reported in the literature. By quantifying the effects that tubing exerted on particle counts, they were assumed to be 38% of the actual dust concentrations. To more closely reflect actual dust concentrations, the hourly means from the dust data set presented in chapter 2 were adjusted using equation (III-2). This chapter will summarize these adjusted values and compare them with literature values. A discussion of the results will also be presented.

RESULTS

Table IV-1 presents the adjusted weekly mean particle concentrations and the range of values of each week. Figures II-5, II-6 and II-7 presented the unadjusted hourly means for each 24-h monitoring period for replicates 1 and 2. Because all dust values were adjusted by the same amount, according to equation (III-2), the

Table IV-1 Weekly means and ranges for particle concentrations (particles/mL) for control, weekly and single mineral oil applications in a farrowing unit

TRT	*CONTROL*		*WEEKLY*		*SINGLE*	
WEEK	*mean*	*range*	*mean*	*range*	*mean*	*range*
1	2.51	1.03-4.62	0.68	0.34-1.94	0.79	0.35-1.98
2	1.68	0.75-3.94	0.72	0.11-1.88	1.63	0.28-6.31
3	5.55	1.24-14.83	0.77	0.30-4.26	5.46	1.04-9.43

dust curves presented in chapter 2 would not change in shape but, if they were replotted, the Y-axis values would go from 0-16 particles/mL, rather than from 0-6. Chapter 2 highlights important trends to be noted from these graphs. Mean adjusted particle concentrations were 2.2 and 2.1 particles/mL for replicate 1 and 2, respectively

and adjusted treatment means are presented in Table IV-2.

Table IV-2 Adjusted mean particle concentration by treatment for control, weekly and single oil applications in a farrowing unit

TREATMENT	*ADJUSTED MEAN PARTICLE CONCENTRATION* (particles/mL)
Control	3.2 [a]
Weekly	0.7 [b]
Single	2.6 [c]

Means with different superscripts are significantly different ($\alpha = 0.05$)
SEM = 0.11

The number of piglets/room was not constant between rooms, and sometimes varied within room from week to week. As stated in chapter 2, ventilation rate was not significantly different by treatment. However, there was some numeric variation in the rates. To account for variation in the number of piglets/room and room ventilation rates, dust production in particles per second per piglet (particles/(s.pig)) was calculated according to equation (IV-1).

$$particle\ production = \frac{particles}{mL} \div \frac{\#\ pigs}{room} \times \frac{1000\ mL}{L} \times \frac{mean\ ventilation\ rate\ L}{s} \qquad \text{(IV-1)}$$

Table IV-3 presents mean particle production rates by treatment. Particle production rate was highest in the control treatment, followed by the single application treatment. Dust production rate was expected to be slightly lower in the single treatment as dust concentrations were much lower during the week of oil application.

Table IV-3 Mean particle production rates (particles/(s.pig)) for control, weekly and single oil applications

	CONTROL	*WEEKLY*	*SINGLE*
Dust production	18644 (595)	4485 (598)	14504 (598)

SEM in parentheses

During the second week, particle production rate more closely approached that of the control treatment (see Table IV-4). Particle production rates increased from weeks 1 to 3. This indicates that as the piglets increased

in size, particle concentrations also increased. However, mean particle concentration during week 2 decreased rather than increased in the control treatment (see Table IV-1). The reason for the decrease was unclear. Nonetheless, the observed decrease would account for the lower particle production rate observed during week 2 of the control treatment. Ventilation rates during week 2 of the control treatment were not higher than those in week 1 or 3. In addition there was not a large change in the number of piglets. Therefore, the reason for the observed decrease was unclear.

Table IV-4 Weekly particle production rates (particles/(s.pig)) for control, weekly and single oil applications

WEEK	*CONTROL*	*WEEKLY*	*SINGLE*
1	14133 (1031)	3900 (1031)	4936 (1031)
2	9519 (1031)	4492 (1031)	8478 (1042)
3	32281 (1031)	5063 (1042)	30097 (1031)

SEM in parentheses

DISCUSSION

Applying oil weekly was an effective means of maintaining low dust concentrations, as seen in Figures II-5 to II-7. Mean dust reduction was 73% for weekly oil application. Dust reduction was 73, 60 and 86% for weeks 1, 2 and 3, respectively. A similar effect was achieved by Takai et al. (1993) who, by applying a rapeseed oil mixture at 5-30 mL oil/pig daily, reduced respirable dust concentration by 76% in buildings housing piglets. The same authors reported a similar effect in rooms housing young pigs and fattening pigs. Mean dust reduction was 54 and 52% in young and fattening pigs, respectively. Preliminary work (Takai, 1987) suggested that applying 40 mL rapeseed oil/m^2 of floor reduced airborne dust concentrations up to 90%.

In studies where oil was applied to poultry litter, similar dust suppressant capabilities were also reported. Taschuk et al. (1991) applied canola oil to turkey litter weekly at a rate of 0.15 mL/m^2. This resulted in a reduction of respirable dust concentrations by 75%, from 49 particles/mL in control rooms, to 12 particles/mL in oil treated rooms. Other work examined the effects of oiling turkey litter and of ventilation rate on dust concentration. Turkeys were housed under high ventilation-oil, high ventilation-no oil, low ventilation-oil or low

ventilation-no oil treatments. Canola oil was applied at a rate of 0.151 L/m^2 once weekly. Applying canola oil to litter was able to reduce respirable dust from 25 to 5 particles/mL, an 80% reduction. Increasing ventilation rate was only able to affect a 65% reduction in dust (23 to 8 particles/mL low vs high ventilation rates, respectively). Lowest dust concentrations were found in the high ventilation-oil treatment. Poorest environment, in terms of dust level was in the low ventilation-no oil treatment (Feddes et al., 1991). In both studies where turkey litter was oiled, dust concentration was the only air quality parameter affected by canola oil application (Taschuk et al., 1991; Feddes et al., 1991).

There were several small differences in room temperatures between treatments and days as discussed in chapter 2. Any differences that were observed are likely the result of differences in ventilation rate from room to room, or from differences in sampling time between days 1 and 2 and day 3. Differences in temperatures were assumed not to influence other parameters.

Average piglet mass was not different by treatment (see Table II-6). Takai et al. (1993) stated that applying a rapeseed oil mixture to floors in pig barns had no effect on pig performance. Gain/day and feed conversion were similar between control and treatment groups. In addition, health status reports from the slaughter house showed that there was no difference in health status between pigs on the oil treatment compared to the control pigs. Similar results have been found with turkeys. Both studies reported no difference in 8, 12 or 16 wk body weights, and there was no difference in feed:gain in either report (Feddes et al., 1991; Taschuk et al., 1991). In both experiments, lungs were removed at slaughter and observed for the presence of lesions. Feddes et al. (1991) reported lesions in 60% of birds housed under no oil-low ventilation. Only 20% of birds under oil-high ventilation had lung lesions. Taschuk et al. (1991) did not find any treatment-related differences in lung lesions in birds on oiled and non oiled litter. However, these birds were housed under a higher ventilation rate (300 L/s) than those in the study by Feddes et al. (1991). This higher ventilation rate may be partially responsible for the lack of difference in lesions between treatments.

When pig lungs were examined for the presence of oil (Takai et al., 1993), there was no evidence of resorption of oil to the upper respiratory tract, lymph nodes or lung tissue. Oil droplets < 5 μm in diameter may travel to the lower respiratory tract. However, no oil droplets were found in the lower respiratory tract

using a sudan III staining technique. Therefore, it would appear that the risk of oil being inhaled by pigs is low. In the study for this thesis, oil was applied under low pressure to ensure that oil droplets were > 5 μm and were therefore not respirable.

Even when particle concentrations were adjusted for the effects of tubing described in chapter 3, particle counts were low compared to literature values in chapter 2. Mean particle concentration in this study was 5.5 particles/mL in the control treatment, with a range of 1.24-14.83 particles/mL. A report by Pedersen (1989) stated that mean respirable dust concentration in Scottish barns was 0.17 mg/m^3, with a range of 0.02-0.4 mg/m^3. Using Choinière and Munroe's (1993) conversion factor presented in chapter 2, this is approximately equal to 2 to 40 particles/mL. Although the percent reduction in dust compared favourably to the literature, the dust levels were lower in both control and oil treatments. There are several possible explanations for this result. The experiment was conducted during the summer, when the ventilation rate is higher. Minimum recommended rate in winter is 7 L/(s.sow) and maximum summer rate is 145 L/(s.sow) (Agriculture Canada, 1988). Mean ventilation rate was 266 L/s. Using a high ventilation rate will reduce dust concentrations, as particulates are more frequently replaced by fresh air (Gao and Feddes, 1993). As stated earlier, Feddes et al. (1991) were able to reduce dust concentrations by 65% by increasing ventilation rate. During winter conditions, ventilation rate is probably 1/10 that of the summer rates. Therefore, dust levels during the winter would more closely match literature values. Phillips (1986) reported that respirable dust concentration during the summer was approximately 1/3 that of the winter.

As mentioned in chapter 2, the experimental facility had a filtered air, positive pressure ventilation system. Air is filtered before entering the rooms. Therefore, any dust in the room is produced by the animals themselves as dust particles are not drawn in from the atmosphere. This may also result in lower dust concentrations than those reported in other swine units.

In addition, the experiment was conducted in a research facility where the standards of hygiene may be somewhat higher than in commercial facilities. Although farrowing crate floors were not cleaned during the 3 weeks of treatment, feed alleys and crate tops were cleaned weekly. This weekly washing may also have kept dust levels lower than what would exist in similar commercial units.

This study was done with young piglets. A dramatic increase in dust concentration was not seen until pigs were approximately 3 weeks of age. Monitoring dust when pigs were 4 weeks of age would probably give dust levels that more closely match literature values for farrowing rooms. However, despite these mean particle concentrations being somewhat low, they do compare favourably with those found by Clark and McQuitty (1988). These researchers reported a maximum daily respirable dust concentration of 9.1 particles/mL and a mean concentration of 7 particles/mL in a batch-farrowing unit with raised crates.

Oil appears to be effective in lowering dust concentrations. It evaporates more slowly than water and may therefore be a good binding agent for dust (Takai, 1987). Particles that come in contact with oil may subsequently adhere to one another, thereby increasing their size (Dawson, 1990). These larger particles will settle out faster. Oil may also help particles adhere to surfaces and prevent their re-entrainment into air. Both of these situations will result in lower concentrations of aerial dust.

Takai et al. (1993) stated that an application rate of 5-10 mL oil/pig applied daily is sufficient to keep particle concentrations low. This may be of particular importance when mineral oil is used. Oil must be applied at a rate sufficient to suppress dust, but at an amount low enough that piglets cannot consume quantities of oil from the floor. The oil application rate in this experiment was 28 and 11 mL oil/piglet, replicates 1 and 2, respectively. The higher application rate allowed pigs to ingest enough oil that a laxative effect was observed. Takai (1987) and Takai et al. (1993) mixed rapeseed oil with a soap and water mixture in order to dilute the oil and ensure that a minute amount of oil was applied to the floors. Using a similar technique with mineral oil may also prevent piglets from ingesting large amounts of oil. Vegetable-based oils, such as canola, soybean or rapeseed, rather than mineral oil, may be able to suppress dust equally well, while not producing adverse side-effects if consumed. More work is needed to determine how long the dust suppressant effects last, and to determine an effective, economically viable application rate. By doing this, we may be able to determine an effective oil application regime that can be automated to control dust in commercial units.

CONCLUSIONS

1. Oil applied weekly was effective in reducing dust concentrations. Mean dust reduction was 73% using weekly oil applications. Mean dust levels during week 3 were 5.55, 0.77 and 5.46 particles/mL

for control, weekly and single treatments, respectively.

2. Applying 24 mL oil/m^2 was sufficient to keep dust levels low while preventing piglets from ingesting oil.
3. Differences in temperatures were the result of differences in ventilation rate. Temperatures only differed by 1-2 ^{o}C and were not expected to influence other parameters.
4. Piglet weights were not significantly different by treatment. Mean piglet mass in week 3 was 5.0 kg for control and weekly treatments and 5.7 kg for the single treatment. Sharpest increase in growth rate occurred between 15 to 30 days of age. This rapid increase in size may, in part, account for the large increase in dust from week 2 to 3.
5. From the results obtained, it is difficult to determine if oil suppresses dust for more than one week. Monitoring twice/wk would more accurately reflect dust suppression over a prolonged period of time.

REFERENCES

Agriculture Canada. 1988. Canadian Farm Buildings Handbook. M. Wolf, S. Rudnitski editors. Research Branch, Agriculture Canada. Publication 1822 E. p. 123.

Choinière, Y. and J.A. Munroe. 1993. Air quality inside livestock barns. OMAF factsheet 93-001. Agdex 400/717.

Clark, P.C. and McQuitty, J.B. 1988. Air quality in farrowing barns. Can. Agric. Eng. 30:173-178.

Dawson, J.R. 1990. Minimizing dust in livestock buildings: Possible alternatives to mechanical separation. J. Agric. Eng. Res. 47:235-248.

Feddes, J.J.R., K. Taschuk, F.E. Robinson and C. Riddell. 1991. Effect of ventilation rate and oiled litter on air quality, health and performance of heavy tom turkeys. Paper. 91-4578. ASAE, St Joseph, MI.

Gao, W. and J.J.R. Feddes. 1993. Using swine dust to verify a lumped-parameter model in a ventilated enclosure. Can. Agric. Eng. 35:67-73.

Pedersen, S. 1989. Dust and gases in livestock buildings. In Proceedings of the 11th International Congress on Agricultural Engineering. Dublin, Ireland. 4-8 Sept. 1989. Vol. 2. Agricultural Buildings. pp. 1489-1494.

Phillips, P.A. 1986. Dust levels in mechanically vs naturally ventilated hog barns. Paper. 86-4041. ASAE, St. Joseph, MI.

Takai, H. 1987. Minimise dust by spraying oil emulsion. Pigs. May/June. 1987. p 13.

Takai, H., F. Møller, M. Iversen, S.E. Jorsal and V. Bille-Hansen. 1993. Dust control in swine buildings by spraying rapeseed oil. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 726-733.

Taschuk, K., J.J.R. Feddes, F.E. Robinson and C. Riddell. 1991. Effect of oiled litter on air quality health and performance of heavy tom turkeys. Paper 91-224. CSAE, Saskatoon, SK.

CHAPTER 5 EFFECTS OF SOW AND PIGLET ACTIVITY ON AIRBORNE DUST CONCENTRATIONS IN A FARROWING UNIT

INTRODUCTION

As seen in previous chapters, applying oil to the floors in farrowing rooms is an effective means of dust control. Airborne particles vary widely in composition and size (Donham et al., 1986), and within livestock environments, there are many factors which can influence airborne dust concentrations. To develop more effective strategies of dust control, it is important to understand the sources of dust and mechanisms by which it is generated (Dawson, 1990). Chapter 1 reviewed the sources of dust in swine barns as well as aerosol composition.

Several factors which can influence particle concentrations include temperature, ventilation rate, stocking density, volumetric airspace/animal, feeding method, nature of feed, moisture content of litter and animal activity (Honey and McQuitty, 1976). Dawson (1990) and MacCormak (1987) stated that high dust concentrations were related to high levels of animal activity and were highest during such husbandry tasks as feeding and weighing animals. This is supported by Cermák and Ross (1978) who studied dust levels in various livestock units during several different husbandry tasks and animal activity levels. Particle concentrations were the highest during periods of high human and/or animal activity.

Animal activity is often referred to as the predominant factor that influences airborne dust concentrations (Dawson, 1990; Feddes et al., 1983; Smith et al., 1993; Honey and McQuitty, 1979; Takai, 1992; Pedersen, 1993). However, DeBoer and Morrison (1988) in their literature review point out that very few studies have characterized or quantified animal activity. Much of the relationship between animal activity and airborne particle concentrations is based on general intuition and subjective evaluation of animal behaviour and activity.

Smith et al. (1993) measured inspirable and respirable dust concentrations during different periods of the day. Dust levels were recorded during morning feeding, midday, afternoon feeding and overnight in a hog barn. Dust concentrations were lowest overnight and highest during feeding periods. Absence of activity overnight was used to explain lower dust concentrations, yet no attempt was made to establish activity levels.

Feddes et al. (1983) stated that dust concentration was significantly affected by temperature and feeding method. In situations of low temperature, it was reported that animal activity was higher, resulting in the higher

dust concentrations. In addition, they suggested that dust generating activities, such as feeding, continue for longer periods in continuously lit rooms. However, no direct measurements of animal activity were made. Takai (1992) evaluated the influence of several factors on aerial dust concentrations. He lists several factors influencing dust, from greatest to least importance as ventilation type, weight or age of pigs, outside temperature, outside relative humidity and inside temperature. However, he also states that animal activity is a major factor causing increased dust emissions, but again no attempt was made to quantify activity. DeBoer and Morrison (1988) state that there is a need for studies where animal activity is quantified and related to aerial dust concentrations.

Pedersen (1993) used a passive infrared detector (PID) to monitor pig activity. This instrument detects motion of objects with a different temperature than that of pen surfaces. Particle concentrations were monitored simultaneously. Using this method, R^2 ranging 0.61-0.85 between animal activity and dust concentration were reported. This means that animal activity accounted for between 61-85% of the variation in dust. This chapter of the thesis not only examined the relationship between animal activity and dust levels, but also studied the influence that specific animal activities had on particle levels.

OBJECTIVES

1. To quantify sow and piglet activity.
2. To relate animal activity to dust concentration.
3. To determine which activities most strongly influence airborne dust concentrations.

MATERIAL AND METHODS

Experimental Facility

This study was also conducted at the Centre for Food and Animal Research swine facility in Nepean, ON. It was conducted between August and October, 1993, under typical Ontario early fall conditions.

One sow and her litter were housed in a room measuring 3.6 x 6.0 x 2.2 m. The animals were housed in a raised farrowing pen, with dimensions of 2.08 x 1.7 m equipped with a farrowing crate. The pen floor was plastic coated expanded metal with no solid portions and was raised 30 cm above the room floor. The ventilation system was identical to that described in chapter 2. The sow was fed once daily at 13:00 and creep feed was provided for piglets *ad libitum*. Animals were housed under continuous light.

Sampling Equipment

Two video cameras, each with a 16 mm lens were focused on the farrowing crate, one over each creep area and were positioned so that all of one piglet creep area and a portion of the sow area were recorded (see Figure V-1). A third video camera, equipped with a 12-75 mm zoom lens was focused on a particle counter (Climet Instrument Co., Redlands, CA) in order to record the dust concentration (>0.5 μm diameter). All three cameras were connected to a quad splitter (Burle, Model TC 1474) to record all three images simultaneously. The quad splitter was connected to a time-lapse video cassette recorder (Panasonic, AG 6720). Both pieces of equipment and a video monitor were housed on a cart that was moved into the room on the day of recording. A microphone was suspended above the sow and connected to the VCR to record animal vocalizations. The particle counter was positioned on a second cart, 2.5 m away from the centre of the farrowing crate. No sampling tube was connected to the instrument. In addition to being recorded on video tape, particle counts were collected and stored on diskette using an IBM PC. See Figure V-1 for the location of sampling equipment.

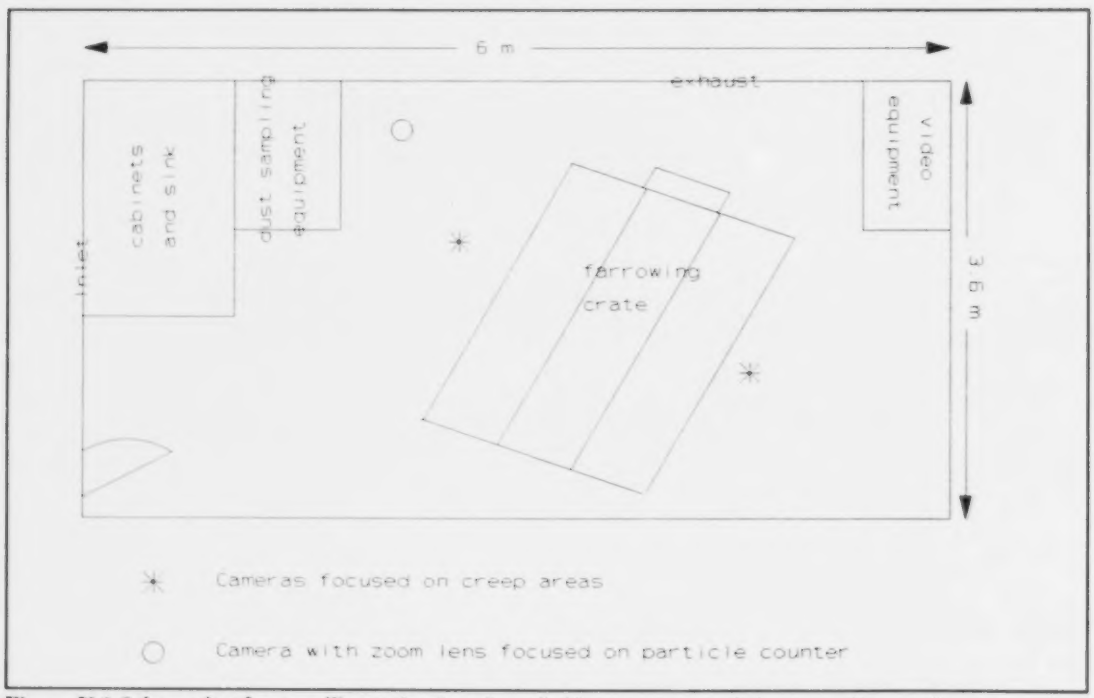

Figure V-1 Schematic of room, illustrating location of video cameras and dust sampling equipment

Experimental Protocol

One sow and her litter (approximately 3 wks of age) were moved into the room. Animals were moved into the room a week before the monitoring period to allow dust to accumulate. Three days before monitoring, daily room washings were discontinued to ensure adequate dust levels. On the monitoring day, the carts with video and dust sampling equipment were positioned in the room as shown in Figure V-1. Video cameras were connected and animal activity recorded continuously for a 6-h period. Number of pigs, pig age, sow and litter number, date and time of recording were also recorded. The VCR was equipped with a date and time stamp that was continuously recorded on the video tape. Dust and video equipment was shut off after 6 h and the particle counts copied to a diskette. The following day, piglets were weaned and the sow removed from the room. The room was then thoroughly cleaned. This procedure was repeated a total of three times, when a litter of pigs of the proper age was available.

Activity Scoring

Dust concentration was plotted vs time (see Figure V-2) and a consecutive 3-h period containing the greatest variation in dust concentration was selected for activity scoring.

As described in chapter 2, the particle counter took 36 s to complete a count. In between counts is a 3-4 s delay. During this delay, the COUNT light on the particle counter extinguishes. Pig activity was scored during this period when the light was extinguished. The corresponding particle count was recorded 36 s later. Piglet and sow activity was divided into several categories. In the case of piglet behaviour, the categories are mutually exclusive, and the number of piglets engaging in each activity category was recorded. In the case of sow activity and nursing episodes, scores were either 1 or 0, where 0 = activity not being displayed and 1 = displayed. Table V-1 shows the activity categories.

In addition to these scores, a further variable was calculated. Proportion active was the percent of visible piglets active and was calculated according to equation (V-1).

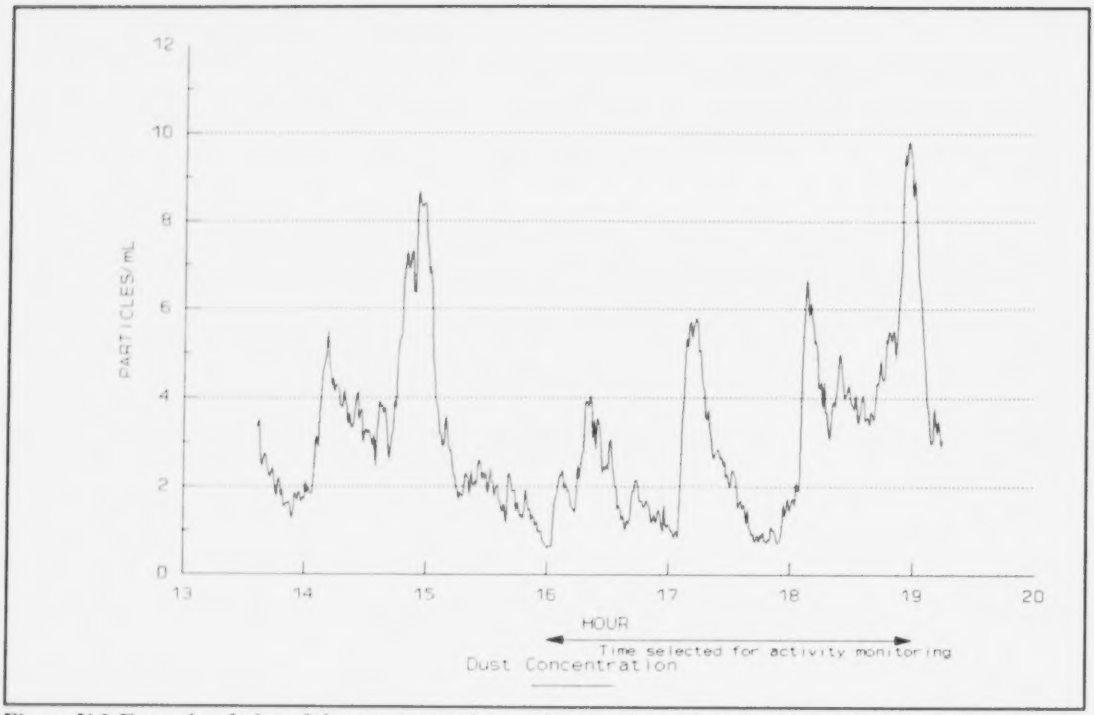

Figure V-2 Example of plot of dust concentration vs time used to select the 3-h period of activity scoring

$$PA = \frac{PS + PIA + PU}{PQ + PLA + PS + PIA + PU} \times 100 \qquad \text{(V-1)}$$

where:

PA = Proportion active
PS = Pigs standing
PIA = Pigs intense activity
PU = Pigs on udder
PQ = Pigs quiet
PLA = Pigs lying active

Table V-1 Categories and criteria used to score piglet and sow activity

ACTIVITY		*CRITERIA*
Pig Quiet	-	piglet lying on side motionless, apparently asleep
Pig Lying Active	-	piglet lying either on sternum or side, appears alert and is moving, does not include short twitches during sleep, these are scored in the previous category
Pig Standing	-	piglet on all fours, either walking or standing still
Pig Intense Activity	-	piglet on all fours, engaged in running, fighting or climbing in to or out of sow feeder
Pig on Udder	-	piglet actively engaged in either suckling, competition for teats or massaging the udder, recorded during nursing episodes only
Sow Sitting	-	sow raised up on fore legs, posterior extremities are on floor
Sow Lying	-	sow lying on either sternum or side
Sow Standing	-	sow on all fours either standing motionless or walking
Nursing Episode	-	half or more of piglets in litter actively engaged in massaging udder, suckling or competing for teat access

NOTE: No attempt was made to distinguish between successful and unsuccessful nursing episodes using audio recording

Statistical Analysis

Data were analyzed using multiple regression. Litter was introduced as the first variable, so that the remaining variation was within litter. Remaining variables were then introduced in a stepwise manner ($\alpha = 0.15$). The amount of additional variation explained by each variable was expressed as a proportion of within-litter variation. In addition, Pearson Partial Correlation Coefficients were calculated to determine the proportion of within-litter variation that each variable contributed on its own. Computations were made using SAS (SAS Institute, 1989, Cary, NC).

RESULTS

Table V-2 shows experimental data on the litters observed. Figure V-2 shows typical variation of dust within a 6-h period. A graph of this nature was plotted for each litter to select the 3-h period for activity

Table V-2 Date and time of recording and age and number of piglets used in activity scoring

LITTER	*DATE*	*TIME OF RECORDING*	*TIME OF OBSERVATION*	*# PIGLETS*	*PIGLET AGE*
1	Aug. 18	13:35-19:47	1549:-19:00	12	28 d
2	Sept. 6	10:09-16:20	10:29-13:30	13	32 d
3	Sept.22	13:01-20:13	13:05-16:05	11	30 d

scoring. Figures V-3, V-4 and V-5 illustrate the relationship between proportion of the litter that was active and the dust concentration. In each of these graphs, there was a small lag time between the increase in activity and the corresponding response in dust. The delay may have resulted in part from the time required for dust generated by the pigs to reach the particle counter at the side of the room. However, to avoid the problems associated with sampling through tubing (see chapter 3), particle counts were recorded directly.

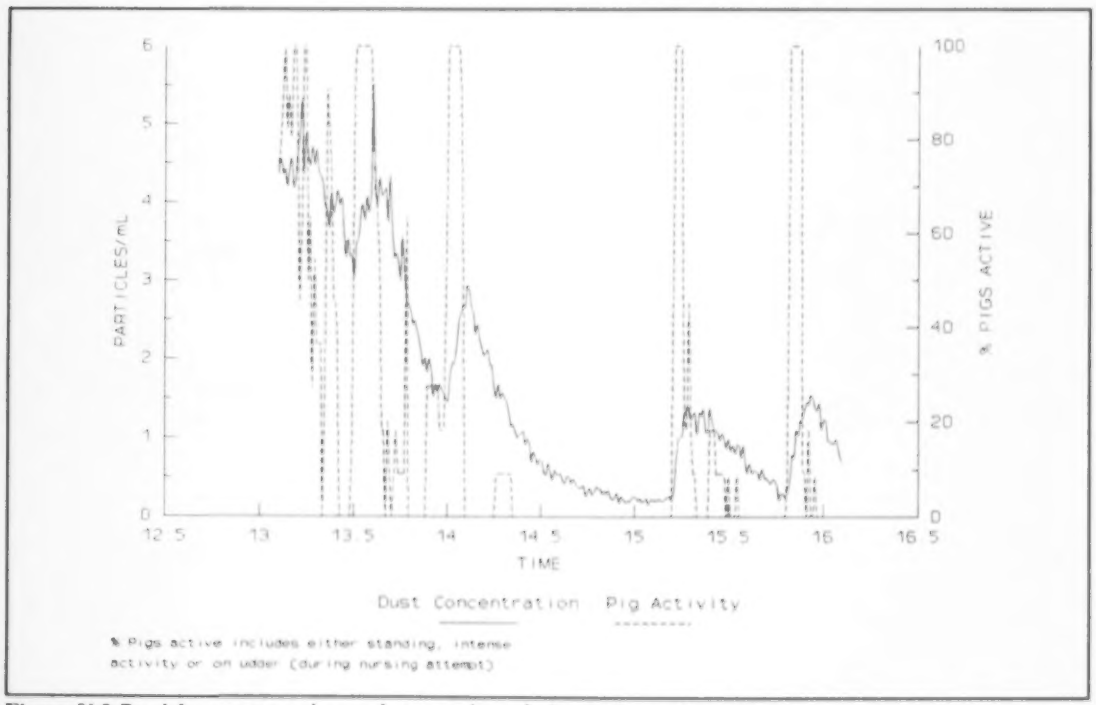

Figure V-3 Particle concentration and proportion of pigs active vs time, litter 3

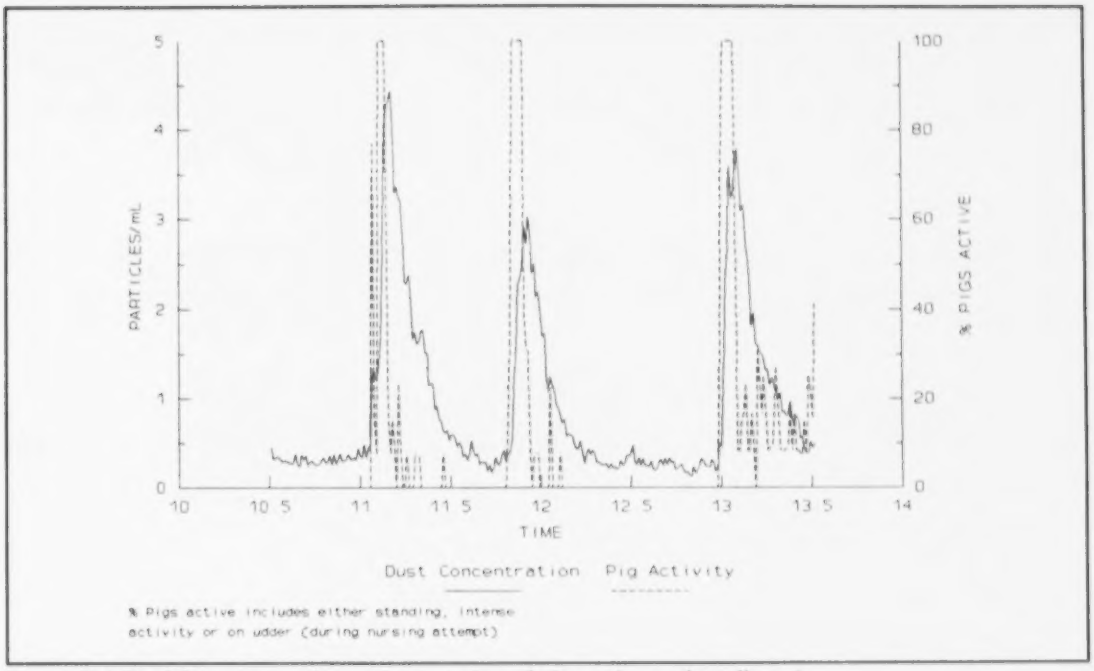

Figure V-4 Particle concentration and proportion of pigs active vs time, litter 2

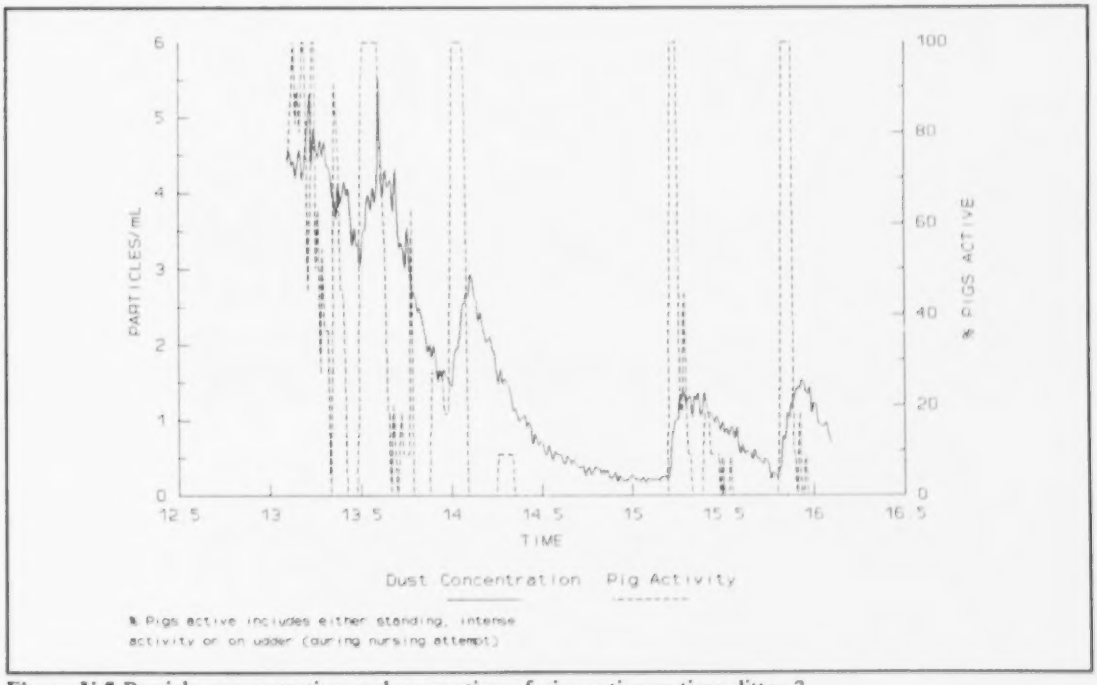

Figure V-5 Particle concentration and proportion of pigs active vs time, litter 3

By removing litter effects, an R^2 of 0.25 was obtained with the unadjusted data. This means that differences between litters explained 25% of the variation in dust. Table V-3 presents the Pearson correlation coefficients for within-litter variation.

Table V-3 Squared Pearson partial correlation coefficients with particle concentration of within-litter variation

ACTIVITY	*SQUARED PARTIAL CORRELATION COEFFICIENTS*	*NATURE OF CORRELATION*
Pigs Quiet	0.46	negative
Pigs Standing	0.29	positive
Pigs Intense	0.14	positive
Pigs on Udder	0.07	positive
Nursing	0.07	positive
Pigs Lying Active	0.07	positive
Sow Standing	0.03	positive
Sow Lying	0.03	negative
Sow Sitting	0.01	positive

Each of the Pearson correlation coefficients indicates the within-litter variation accounted for if the variable is entered into the model on its own. For example, if one considers only the number of pigs standing, 29% of the variation in particle concentration is explained.

In addition, data were analyzed using stepwise regression of within-litter variation in order to determine which activity categories were most important in influencing dust concentration (see Table V-4). The partial R^2 illustrated the additional amount of variation explained, provided that the previous variables have been entered into the model.

Proportion active took all of the piglet activities into account. When litter effect was accounted for, the proportion of piglets active explained 29% of within-litter variation ($p = 0.0001$) (see Table V-5).

Table V-4 R-squares and partial R-squares for stepwise regression of within-litter variation

ACTIVITY	R^2	*PARTIAL* r^2
Litter	0.25	-
Pigs Quiet	0.60	0.35
Pigs on Udder	0.63	0.03
Pigs Intense Activity	0.65	0.02
Sow Sitting	0.66	0.01

Table V-5 R-squares and partial R-squares for proportion of piglets active

VARIABLE	R^2	*PARTIAL* r^2
Litter	0.25	-
Proportion Active	0.54	0.29

DISCUSSION

When considered on its own or in a stepwise regression, number of piglets quiet explained the greatest amount of within-litter variation of dust concentration. The relationship is negative, indicating that the more pigs inactive, the lower the particle concentration. This agrees with the results of Smith et al. (1993) (see page 48).

Again the dust levels encountered in this experiment were rather low presumably because only one sow and litter were housed in the room and dust levels were likely diluted by the larger air volume. Nonetheless, there was a clear relationship between animal activity and airborne dust. Litter effects explained 25% of variation in dust. This could be the result of differences in the number of piglets, age or weight of piglets, or differences in general activity between litters. The proportion of active piglets explained 29% of within-litter variation. Using PID, Pedersen (1993) obtained R^2 values of 0.61, 0.85 and 0.67 between pig activity and dust concentration. That experiment was conducted on pigs with an average weight of 28 kg. However, when dust and activity were plotted vs time, a time lag opposite to the one observed here was found. In Pedersen's report,

increases in dust concentration were found to precede increased activity. The opposite was reported here. Increases in dust concentration followed increased activity. R^2 values in this study are much lower than those reported by Pedersen (1993). There are 2 reasons for this. One is the time delay between dust generation and its detection by the particle counter, discussed earlier. The second reason is that particle counts remain elevated for a prolonged period after activity has returned to low levels. Both of these factors combined to lower the amount of within-litter variation explained by each variable.

The eventual decrease in particle levels seen in Figures V-3 to V-5 was probably the result of particles being removed by ventilation rather than by settling on to surfaces. This indicates the need for effective dust control even after periods of intense activity. This may be of particular importance in farrowing units. Although nursing was not one of the more important activities in generating dust, nursing episodes did result in increased particle concentrations. Once litter effects were removed, number of pigs on the udder was the second variable to enter the stepwise regression, after pigs quiet. Most of the spikes in dust concentration occurred during a nursing episode. Dust concentrations may just be beginning to return to low levels when activity increases and subsequently increases the dust concentration. Therefore, the need to control airborne dust during the entire day may be important to protect the health of swine labourers in these environments. In the case of older animals, activity levels may be high only during periods of human activity, such as feeding, weighing or other handling of animals. In these situations, applying a dust suppressant such as oil before these periods may be all that is required to protect worker health.

There are many methods available to monitor animal activity. Pedersen (1993) suggests that video recording is too time consuming to establish a relationship between activity and dust concentrations. Noise recording can be used as an indirect measure of activity. However, there is a low correlation between noise levels and animal activity (Pedersen, 1993). Feddes et al. (1983) attempted to record sound as a means of determining animal activity. However, this was unsuccessful due to excessive background noise and cross-sensitivity between rooms. Sound was originally recorded in this author's study to aid in distinguishing between successful and unsuccessful nursing episodes. During a successful milk ejection, frequency of sow vocalizations increases (D. Fraser, personal communication, 1993). However, this technique was not used for two reasons.

During a nursing period, background noise was often high enough to obscure sow vocalizations. In addition, regardless of whether nursing was successful, piglet activity levels were similar and therefore determining success of nursing was discontinued.

Although time consuming, video recording is a valuable tool in relating animal activity and dust. Honey and McQuitty (1979) list several factors that influence particle concentrations from greatest to least importance as:

animal activity,
temperature,
relative humidity,
amount of feed fed,
feeding method,
pig weight and
airflow rate.

This study indicates a relationship between piglet activity and particle concentration does exist.

CONCLUSIONS

1. Litter effects explained 25% of the variation in dust. Differences between litters may be the result of differences in the number, age or weight of piglets.
2. Number of piglets lying quietly explained the greatest amount of within-litter variation and was inversely related to dust levels. When considered on its own, number of piglets lying quietly gave $R^2 = 0.46$. When entered into the model in a stepwise manner, it was the first variable to enter and resulted in a partial $r^2 = 0.35$.
3. Number of piglets standing or engaged in intense activity also accounted for large variations in dust concentrations. When entered into the model on their own, piglets standing and those in intense activity gave $R^2 = 0.29$ and 0.14, respectively. When considered in a stepwise fashion, pigs on the udder was the second variable to enter the model, and partial $r^2 = 0.03$.
4. Sow activity explained little of the within-litter variation in dust. When each variable is considered on its own, $R^2 = 0.03$ for standing and lying both, and 0.01 for sitting. When entered in a stepwise fashion, partial r^2 for within-litter variation was 0.01 for sitting.
5. Using proportion of pigs active may also be useful in relating animal activity and dust concentration.

Proportion of visible pigs active explained 29% of within-litter variation.

6. There is a strong relationship between piglet activity and dust concentration. Highest dust levels occur during periods of high activity and remain elevated for a prolonged period.

REFERENCES

Cermák, J.P. and P.A. Ross. 1978. Airborne dust concentrations associated with animal housing tasks. Farm Building Progress. 51:11-15.

Dawson, J.R. 1990. Minimizing dust in livestock buildings: Possible alternatives to mechanical separation. J. Agric. Eng. Res. 47:235-248.

DeBoer, S. and W.D. Morrison, 1988. The effects of the quality of the environment in livestock buildings on the productivity of swine and safety of humans. A Literature Review. Dept. of Animal and Poultry Science. University of Guelph. Guelph, ON.

Donham, K.J., L.J. Scallon, W.A. Popendorf, M.W. Treuhaft and R.C. Roberts. 1986. Characterization of dusts collected from swine confinement buildings. Am. Ind. Hyg. Assoc. J. 47:404-410.

Feddes, J.J.R., J.J Leonard and J.B. McQuitty. 1983. The influence of selected management practices on heat, moisture and air quality in swine housing. Can. Agric. Eng. 25:175-179.

Honey, H.F. and J.B. McQuitty. 1976. Dust in the Animal Environment. Dept. of Agricultural Engineering. University of Alberta. Research Bulletin 76-2.

Honey, L.F. and J.B. McQuitty. 1979. Some physical factors affecting dust concentrations in a pig facility. Can. Agric. Eng. 21:9-14.

MacCormak, J.A.D. 1987. Respiratory disease in pigs - housing interactions. Farm Building Progress. 88:9-10.

Pedersen, S. 1993. Time based variation in airborne dust in respect to animal activity. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 718-725.

Smith J.H., C.R. Boon and C.M. Wathes. 1993. Dust distribution and airflow in a swine house. Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 657-662.

Takai, H. 1992. Aerial dust in swine buildings. Roomvent '92. Air Distribution in Rooms. 3rd International Conference. Aalbourg, Denmark. Sept 2-4. 1992. pp. 105-117.

CHAPTER 6 GENERAL DISCUSSION AND CONCLUSIONS

Although intensification of livestock housing has facilitated more efficient use of labour, it presents special challenges to stockpersons. One such challenge is ensuring adequate air quality for both the animals and humans in these environments. Time weighted average exposure limits are 10 and 5 mg/m^3 for total and respirable dust, respectively (OSHA, cited by Choinière and Munroe, 1993). However, Donham et al. (1986) suggest that exposure limits for nuisance dusts may not be adequate for biologically active dusts such as those present in livestock barns. In order to better protect the respiratory health of labourers and animals, they recommend lower exposure limits, shown in Table I-5 .

Several years ago, the main health and safety concern in agriculture was that of farm accidents. Now however, strong evidence exists to suggest that farm labourers have a higher incidence of respiratory disability than industrial workers (Hellickson et al., 1989). Major respiratory symptoms of swine workers included cough, chest tightness, excess sputum, wheezing and shortness of breath (Donham and Gustaffson, 1982). Symptom severity and incidence increased with smoking and also as the number of pigs raised increased (Donham, 1987; Donham and Gustaffson, 1982; Donham et al., 1990). In addition, current smokers had more frequent bronchitic and reactive symptoms than non-smokers (Donham et al., 1990). However, Donham and Gustaffson (1982) reported no correlation between worker age, number of hours worked/wk, type of building or operation and pulmonary score. In a survey of turkey labourers, Hellickson et al. (1989) reported significantly higher respiratory complaints in older workers. Their study suggested that wearing masks may provide some respiratory protection. One of the Hutterite colonies surveyed was very conscientious about wearing masks while working. This colony had significantly lower prevalency rates for 3 months cough, morning cough and phlegm production, even though the air quality was often poorest in this barn. However, a study of self-reported behaviours of swine workers found that < 20 % wore masks regularly (Gjerde et al., 1991).

Therefore, means of controlling dust within livestock barns have been investigated. Oil has been added to feed to reduce the release of airborne feed particles (Chiba et al., 1985, 1987; Gast and Bundy, 1986; Gore et al., 1986; Welford et al., 1990 and Xiwei et al., 1993), or to grain (Wardlaw et al., 1989). Researchers have also added oil to litter in poultry barns (Feddes et al., 1991; Taschuk et al., 1991) or to floors in swine barns

(Takai, 1987; Takai et al., 1993). In all cases, applying oil was able to reduce dust.

This study was conducted to examine the effect of floor-applied mineral oil on dust concentrations in a farrowing unit. Oil was applied weekly or applied once during a 3 week period. During the course of preliminary work, it was discovered that sampling technique was having a negative effect on particle counts obtained. Therefore a 5 x 5 Latin square design, using 0, 4.6, 9.2, 13.8 and 18.4 m of tubing was performed to quantify the effect that sampling technique had on particle counts. Particle counts obtained using the remote sampling technique described were only 38% of what they would have been if no tubing was used. The reason for the observed effect was unclear, and is believed to be unique to the particular type of tubing used in this study. Results from the experiment involving mineral oil were adjusted for this effect. Applying oil weekly resulted in a mean reduction of respirable dust by 73%. An application rate of 24 mL/m^2 was sufficient to maintain low dust levels while ensuring that piglets were not able to consume quantities of oil from the floor. Mean dust concentrations were 3.2, 0.7 and 2.6 particles/mL for control, weekly and single applications, respectively. However, care must be taken when applying oil to control dust. Oil must be applied at a rate and in a manner which does not make floors noticeably slippery for the animals. More work is needed to determine application rates and regimes that will ensure dust control while using a minimum of oil. Vegetable based oils may provide similar dust suppressant capabilities while not possessing negative side effects if ingested. They may also be a more inexpensive alternative to mineral oil. Additional work testing oil's effectiveness in other units such as weaner and grower-finisher facilities may also be needed before this technology is widely adopted.

However, to develop effective particle control strategies, it is important to understand the means of airborne particle generation and the factors that influence dust concentrations. Many factors can influence dust and often animal activity is reported as a major causal agent of elevated concentrations. In spite of this, few studies have quantified animal activity and related it to aerosol concentrations. Chapter 5 describes the experiment conducted to examine the relationship between animal activity and dust. The number of pigs in each activity category was recorded, and sow activity and nursing episodes were recorded. In addition, the proportion of visible pigs active was calculated from all piglet activity categories. As shown in figures V-3-5, a strong relationship between piglet activity and dust concentration exists. The number of pigs quiet explained the

greatest amount of within-litter variation in particle levels. Sow activity had little influence on dust levels. However, the range of activity that a sow can exhibit is severely limited in a farrowing crate. This may partially explain why sow variables explained such a small portion of the variation in dust concentration. The proportion of visible pigs active explains 37% of within-litter variation. This is lower than that found by Pedersen (1993). Using a passive infrared detector, he found an R^2 of 0.61-0.85 between pig activity and aerial dust. However, the PID system is one of motion detection rather than actual activity classification and this may help explain the difference in results.

Variations in animal activity do explain large fluctuations in particle concentration. Therefore it may be possible to devise dust control strategies that are activated before periods of high human or animal activity, such as feeding, weighing or moving pigs. For example, in a system where oil is applied to floors, the spraying system could be mechanized and put on an automatic timer. The timer could be set to come on during a period of high activity, such as when lights come on, or just prior to feeding. This would aid in keeping particle concentrations low during the work day and may improve animal respiratory health as well. From these studies, it is obvious that control measures are needed to limit worker exposure to potentially harmful concentrations of swine house dusts. It is important that low-maintenance, easy to use methods to improve air quality within livestock barns are developed. A system of floor-applied oil could be easily mechanized and timed automatically to provide a low maintenance, effective means of controlling respirable dust concentrations in swine barns.

REFERENCES

Chiba, L.I. E.R. Peo Jr. and A.J. Lewis. 1987. Use of dietary fat to reduce dust, aerial ammonia and bacterial colony forming particle concentrations in swine confinement buildings. Trans. ASAE. 30:464-468.

Chiba, L.I., E.R. Peo Jr., A.J. Lewis, M.C. Brumm, R.D. Fritschen and J.D. Crenshaw. 1985. Effect of dietary fat on pig performance and dust levels in modified open front and environmentally regulated confinement buildings. J. Anim. Sci. 64:763-781.

Choinière, Y. and J.A. Munroe. 1993. Air quality inside livestock barns. OMAF factsheet 93-001. Agdex 400/717.

Donham, K.J. 1987. Human health and safety of workers in livestock housing. In Latest Developments in Livestock Housing. Seminar of the 2nd Technical Section of the Commision du Génie Rural. 22-26 June, 1987. University of Illinois. Champaign, Ill. pp. 86-95.

Donham, K.J. and K.E. Gustaffson. 1982. Human occupational hazards from swine confinement. Ann. Am. Conf. Gov. Ind. Hyg. 2:137-142.

Donham, K.J., J.A. Merchant, D. Laisse, W.J. Popendorf and L.F. Burmeister. 1990. Preventing respiratory disease in swine confinement workers: Intervention through applied epidemiology, education and consultation. Am. J. Ind. Med. 18:241-261.

Donham, K.J., L.J. Scallon, W.A. Popendorf, M.W. Treuhaft and R.C. Roberts. 1986. Characterization of dusts, collected from swine confinement buildings. Am. Ind. Hyg. Assoc. J. 47:404-410.

Feddes, J.J.R., K. Taschuk, F.E. Robinson and C. Riddell. 1991. Effect of ventilation rate and oiled litter on air quality, health and performance of heavy tom turkeys. Paper 91-4578. ASAE, St. Joseph, MI.

Gast, R.M. and D.S. Bundy. 1986. Control of feed dusts by adding oils. Paper 86-4039. ASAE, St. Joseph, MI.

Gjerde, C., K. Ferguson, C. Mutel, K. Donham and J. Merchant. 1991. Results of an educational intervention to improve the health knowledge, attitudes and self-reported behaviours of swine confinement workers. J. Rural Health. 7:278-286.

Gore, A.M., E.T. Kornegay and H.P. Veit. 1986. The effects of soybean oil on nursery air quality and performance of weanling pigs. J. Anim. Sci. 63:1-7.

Hellickson, M.A., E.H. Schlenker, M.A. Schipull, D.P. Froelich and R.R. Parry. 1989. Effects of dust and gases on labourers in livestock confinement buildings. In Agricultural Engineering. Proceedings of the 11th International Congress on Agricultural Engineering. 4-8 Sept., 1989. Volume 2. Agricultural Buildings. pp. 1471-1478.

Pedersen, S. 1993. Time based variation in airborne dust in respect to animal activity. In Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 718-725.

Takai, H., F. Møller, M. Iversen, S.E. Jorsal and V. Bille-Hansen. 1993. Dust control in swine buildings by spraying rapeseed oil. In Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 726-733.

Taschuk, K., J.J.R. Feddes, F.E. Robinson and C. Riddell. 1991. Effect of oiled litter on air quality health and

performance of heavy tom turkeys. Paper 91-224. CSAE, Saskatoon, SK.

Welford, R.A., J.J.R. Feddes and E.M. Barber. 1992. Pig building dustiness as affected by canola oil in the feed. Can. Agric. Eng. 34:365-373.

Xiwei, Li, J.E. Owen, A.J. Murdoch and C.C. Pearson. 1993. Respirable dust from animal feeds. In Livestock Environment IV. Proceedings of the 4th International Livestock Environment Symposium. University of Warwick. Coventry, England. 6-9 July, 1993. pp. 747-753.

APPENDIX FOR CHAPTER 2

1. Calculation of Oil Application Rate for Room with 6 Farrowing Crates per Room

$$\text{application rate for rooms with 5 crates per room} = 250 \text{ mL}$$

$$\therefore \text{application rate} \quad \frac{250 \text{ mL/crate}}{4.12 \text{ m}^2\text{/crate}} = 61 \text{ mL oil/m}^2$$

$$\therefore \text{6 crates/room each with an area of } 3.39 \text{ m}^2$$

$$61 \text{mL/m}^2 \times 3.39 \text{ m}^2 = 207 \text{ mL oil/crate}$$

2. Calculation of Application Rate Used in Replicate 2

$$\text{using } 100 \text{ mL/crate in rooms with 5 crates/room} \quad \frac{100 \text{ mL/crate}}{4.12 \text{ m}^2\text{/crate}} = 24 \text{ mL/m}^2$$

$$\therefore \text{in room with 6 crates/room} \quad 24 \text{ mL/m}^2 \times 3.39 \text{ m}^2\text{/crate} = 81 \text{ mL/crate}$$

3. Calculation of Factor to Convert Particles/0.01 CF to Particles/mL

$$\frac{\text{particles}}{0.01 \text{ CF}} \times 100 \times \frac{35.31 \text{ CF}}{1 \text{ m}^3} \times \frac{1 \text{ m}^3}{1000 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}}$$

$$\therefore \frac{\text{particles}}{0.01 \text{ CF}} \times 0.00353 = \frac{\text{particles}}{\text{mL}}$$